



USEPA ASPECT Program

Airborne Spectral Photometric Environmental Collection Technology

NATION'S ONLY

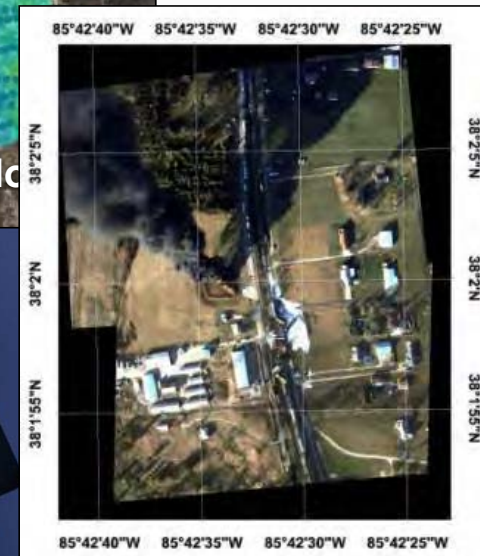
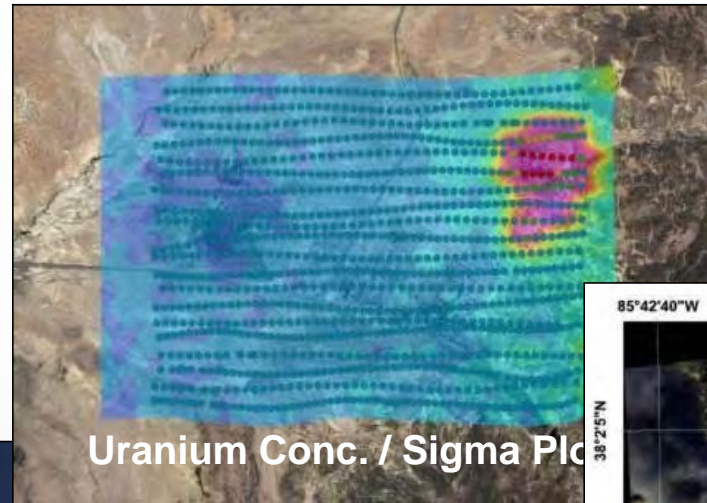
-Remote-Sensing & Imagery-

Chemical, Radiological & Situational Awareness



ASPECT Overview Objectives

- Operational Concept
- ASPECT Systems
- ASPECT Capabilities
- Response Examples
- Detailed Pattern Recognition method
- Detailed Passive Quantification method



IR Image @ DWH

Multi-Role Concept



Emergency Response

Homeland Security

Removal/Remedial Characterization



Users/Partners include EPA, NGA, DHS, DOE, DOD, NGB, DOJ, USSS, NASA, FEMA, USCG, States

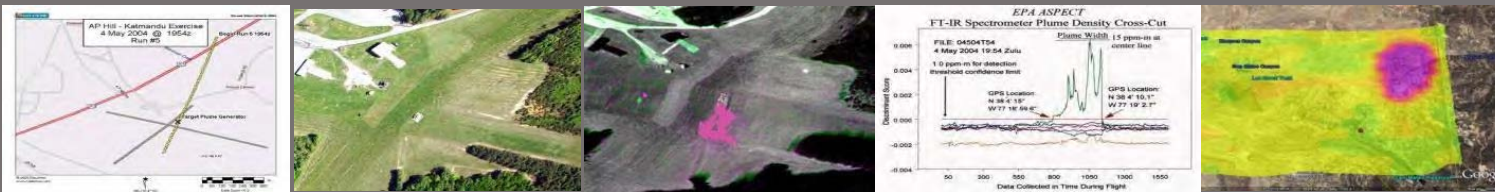
The primary role of the ASPECT program is emergency response. The system serves as a queuing device and permits a fast hazard screening to be conducted at the scene.

ASPECT - Operational Concept

- Provide a readiness level on a 24/7 basis
- Provide a simple, one phone call activation of the aircraft
- Wheels up in under 1 hour from the time of activation
- Once onsite and data is collected it takes about....



~ 5 minutes to process and turn around data to first responders



- **Deployment Simplified:**
 - Once on-scene collect chemical, radiological, or situational data (imagery) using established collection procedures
 - Process all data within the aircraft using tested automated algorithms
 - Extract the near real time data from the aircraft using a broadband satellite system and rapidly QA/QC the data by a dedicated scientific reach back team
 - Provide the qualified data to the first responder enabling them to make informed decisions in minimal time

ASPECT -CURRENT SYSTEMS

ASPECT Uses Six Primary Sensors/Systems:

- ✓ An **Infrared Line Scanner*** to image the plume
- ✓ A **High Speed Infrared Spectrometer*** to identify and quantify the composition of the plume
- ✓ **Gamma-Ray Spectrometer** Packs for Radiological Detection (NaI and LaBr) and two **BF₃ Neutron Detector arrays**
- ✓ High Resolution **Digital Aerial Cameras*** with ability to rectify for inclusion into GIS
- ✓ Broadband Satellite Data System (**SatCom**)

*29 MP Mapping and 12.5 MP Nikon DX2 DSLR



Deployments & Range

- Over 160 deployments
- ~500 Sorties (flights)
- 67 Emergency Responses
- 24+ Scientific Studies
- Numerous FTXs
- SEAR & NSSEs
- Utilized by all EPA Regions
- Federal, HRF, CST
- International Notoriety
- Terabytes of Data



Estimates Include:

1. 1 hour prep
2. Refueling stop
3. >1 hour data collection

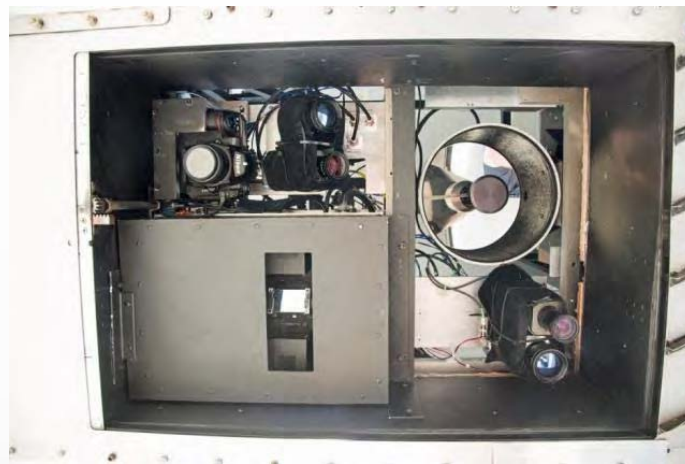
Communications:

1. Real-time status
2. Flight parameters developed & uploaded while in-flight
3. Preliminary products in-flight

Safety/Regulation:

1. Fully FAA Certified Aircraft and Pilots
2. FAR Part 91
3. FAR Part 135

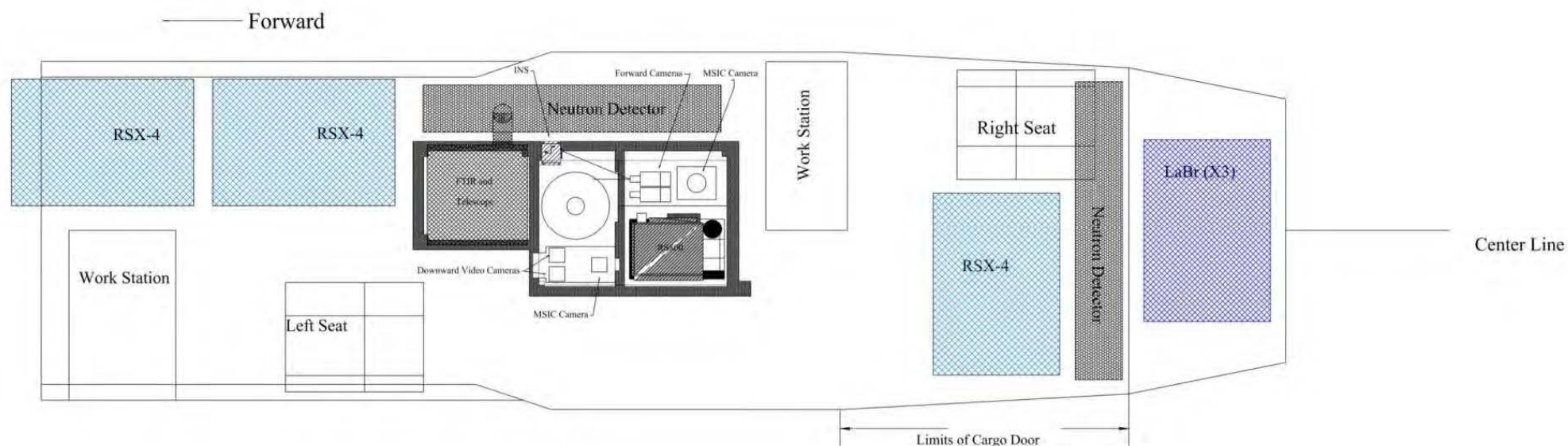
N9738B Cessna 208B Cargo master



System:	Single Engine Turbo-Propeller Driven Aircraft
Make:	Cessna 208B Cargo Master, Part 91 Certification
Power Plants:	Pratt and Whitney PT-6A-114B turbine driven three blade propeller, 675 shaft HP
Empty Weight:	4458 lbs.
Useful Weight:	4604 lbs. (2000 lbs of payload after fuel and crew!)
Maximum Take-off Weight:	9062 lbs.
Typical Cruise Speed:	160 Kts
Typical Flight Duration:	6 Hours (65% Power) Plus 45 Minute Reserve
Service and Ceiling:	Low Altitude Waiver, 25000 Ft (MSL) max altitude
Cabin:	Un-pressurized, Crew Oxygen
Portals:	One, 20 X 30 inch DER sensor hole with Remote Door
Exhaust Mod	Full DER Exhaust Bypass
Electrical Buss:	Primary, 28 vdc @ 200 amps full load, Secondary, 28 vdc @ 90 amps full load
Data Communication:	Phased Array Satellite System, 40-60 KB/sec Data/Telephone combined, STC
Readiness Status:	24/7/365
FAA Status	Part 91, Restricted Use (Sensors Only), Full Compliance



ASPECT -CURRENT SYSTEMS AND LAYOUT



ASPECT Optical/IR Sensor Layout

Bottom View



MSIC Mapping Camera

IR Targeting Camera

Visible Targeting Camera

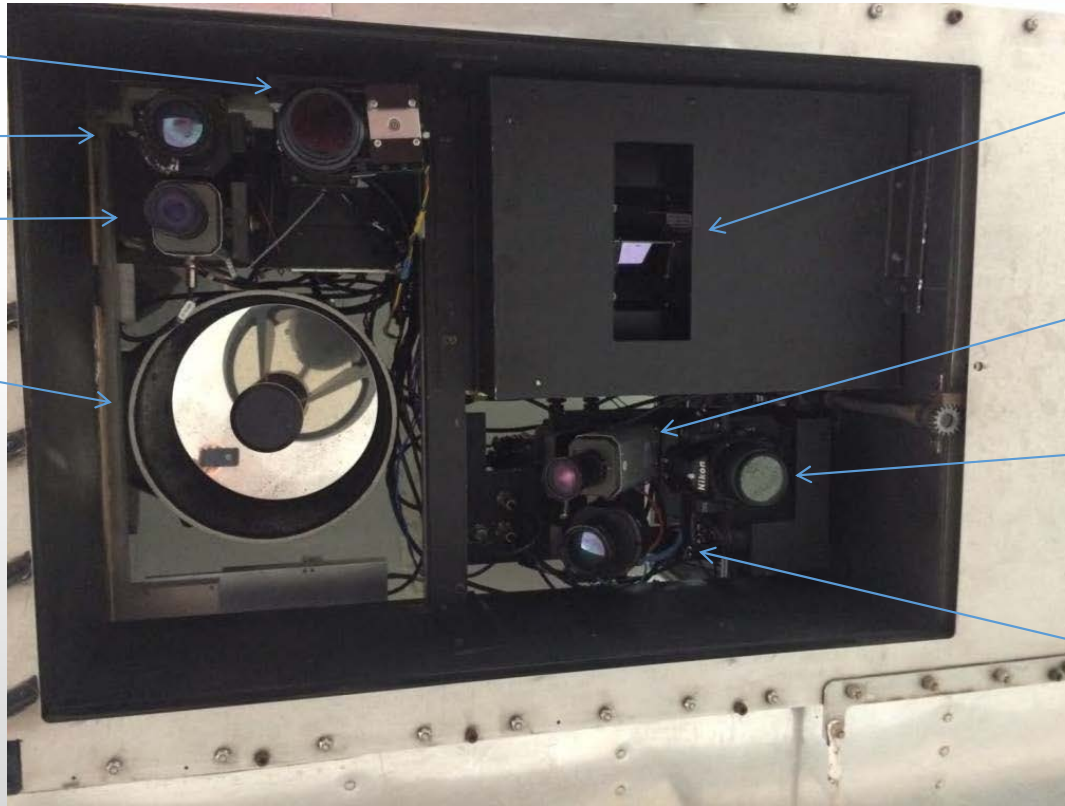
Spectrometer Telescope

RS800/LS1600 IR Scanner

Visible Forward Targeting Camera

Nikon D2X Camera Reserve

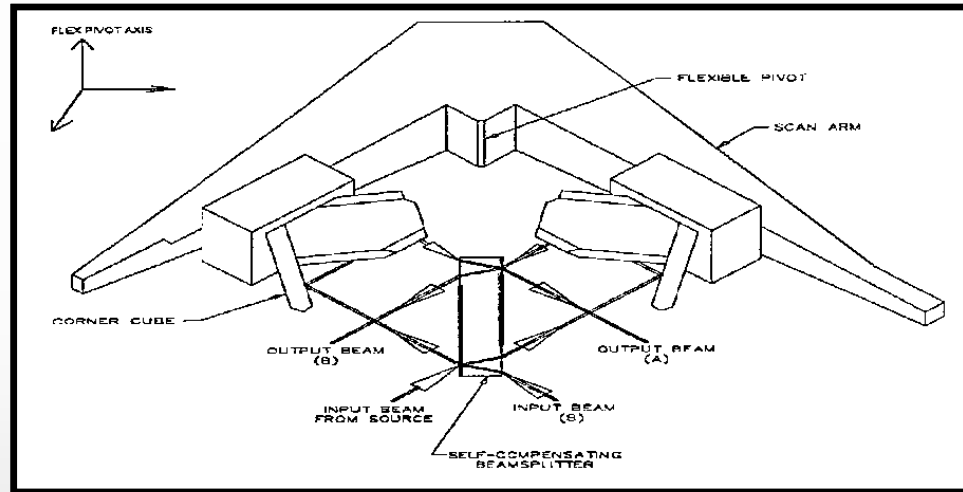
IR Forward Targeting Camera



← Front



ASPECT FTS System



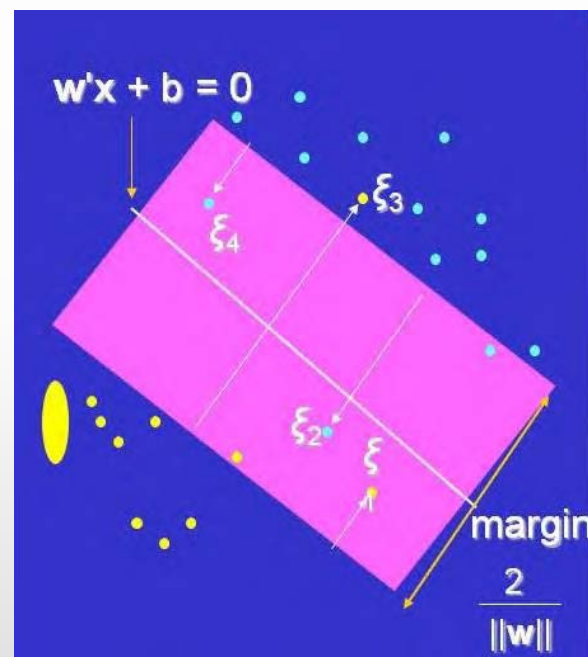
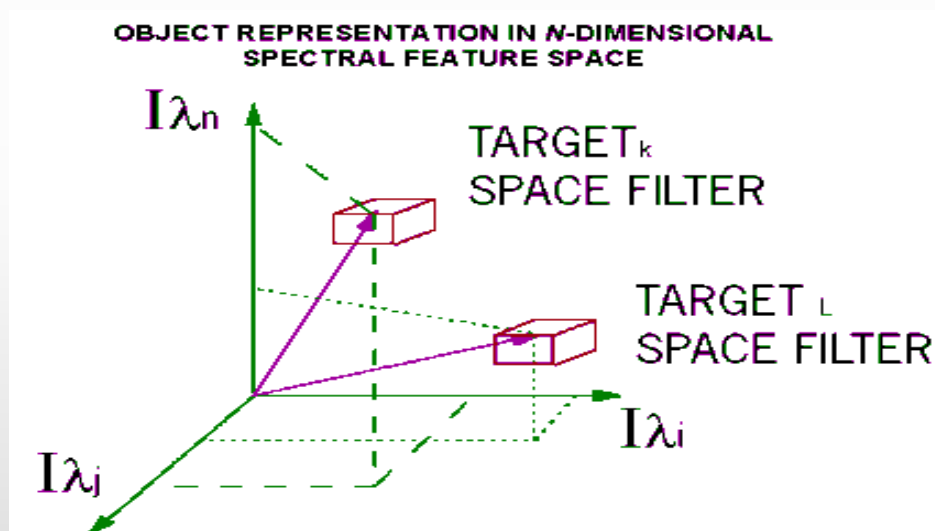
INTERFEROMETER DESIGN

- Scan Speed - 87 scans/sec
- Telescope - 10" (0.2° FOV)
- Dual Scan Direction
- Throughput - 0.01 cm²*sr
- Thermal Stabilization
- Controlled Blackbody
- 1.0 to 32 cm⁻¹ resolution

- Channel 1 : 3 - 5 microns $6 \times 10^{-9} \text{ W/cm}^2 \text{sr cm}^{-1}$
- Channel 2 : 8-12 microns $1.8 \times 10^{-8} \text{ W/cm}^2 \text{sr cm}^{-1}$
- Noise Equivalent Response

ASPECT

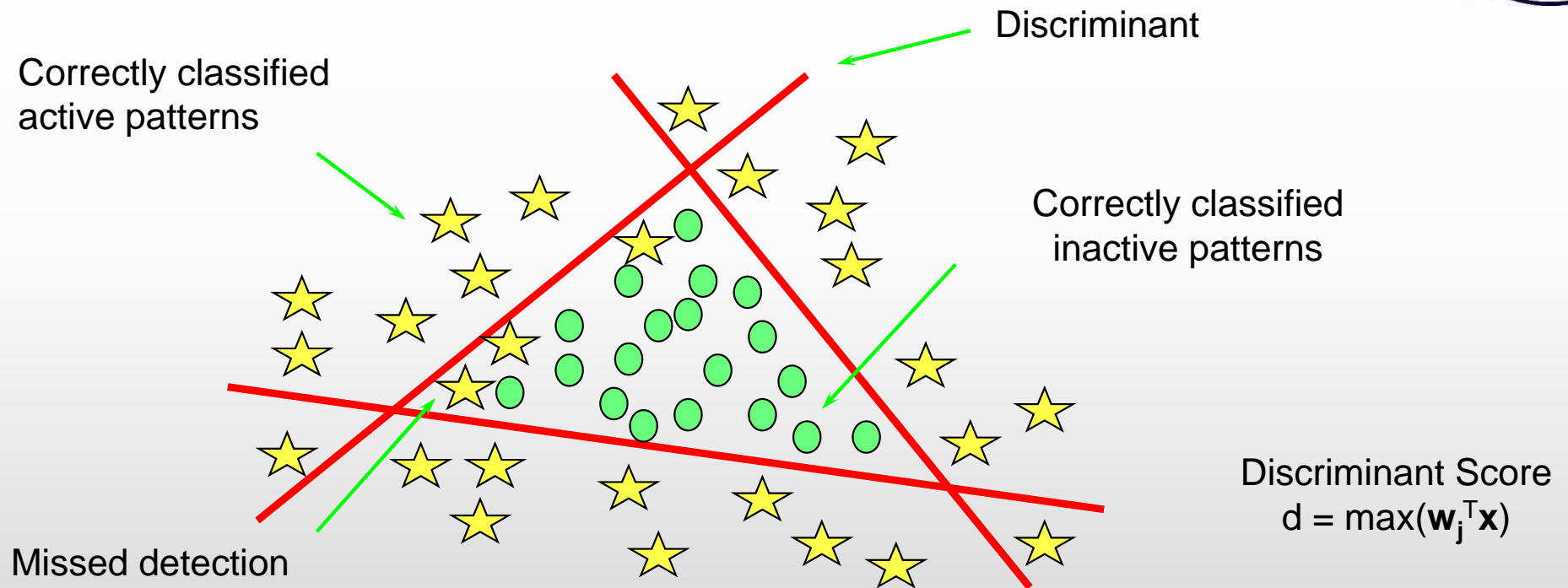
Multi-Dimensional Space Pattern Recognition



Output from the digital filter process is input into a n -dimensional pattern recognition routine using either a piece wise linear discriminator or a support vector machine discriminator. These routines map the vector space (patterns) into similar dimensional space.

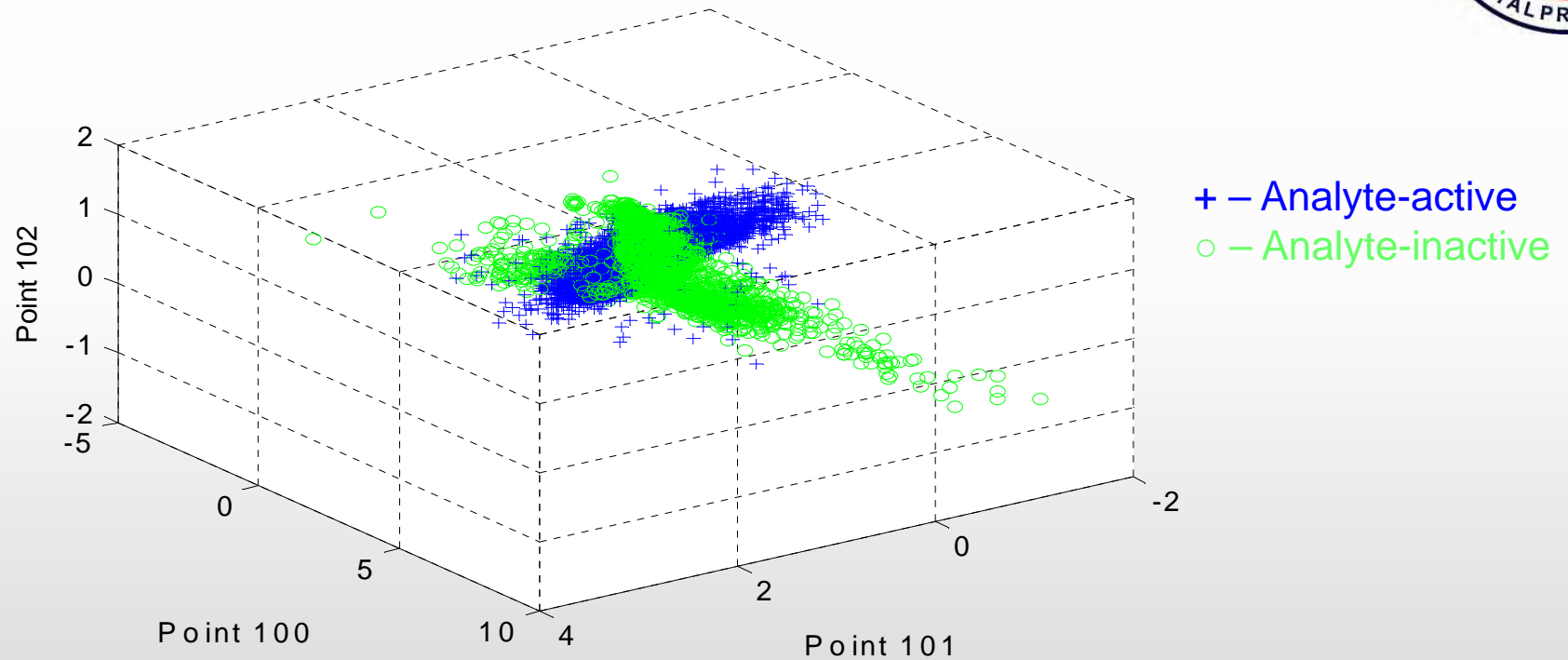
ASPECT

Piecewise Linear Discriminant Analysis



ASPECT uses about 100 dimensions of data!

ASPECT Training Set



Defines the data space corresponding to active and inactive patterns

Source: University of Iowa

ASPECT

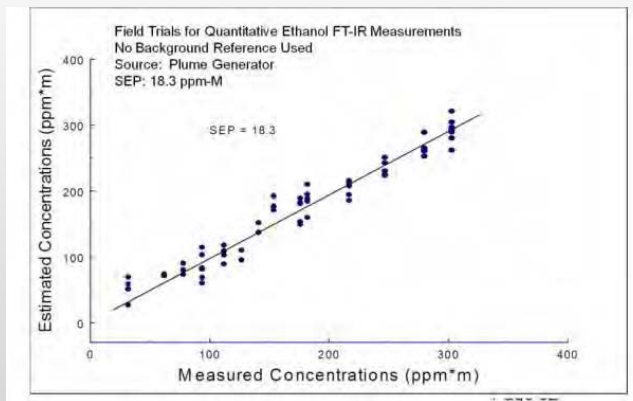
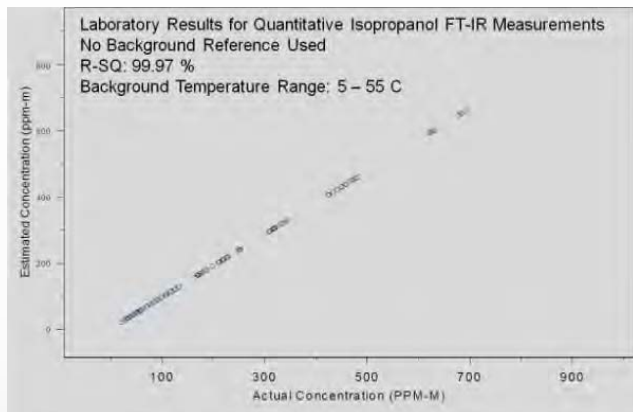
Detection Limits (in ppm*m)



Acetic Acid (20)	Cumene (200)	Isoprene (65)	Propylene Oxide (68)
Acetone (5)	Diborane (50)	Isopropanol (85)	Silicon Tetrafluoride (2)
Acrolein (88)	1,1-Dichloroethene (37)	Isopropyl Acetate (7)	Sulfur Dioxide (150)
Acrylonitrile (125)	Dichloromethane (60)	MAPP (37)	Sulfur Hexafluoride (0.7)
Acrylic Acid (33)	Dichlorodifluoromethane (7)	Methyl Acetate (10)	Sulfur Mustard (60)
Allyl Alcohol (53)	1,1-Difluoroethane (8)	Methyl Ethyl Ketone (75)	Nitrogen Mustard (25)
Ammonia (20)	Difluoromethane (8)	Methanol (54)	Phosgene (5)
Arsine (187)	Ethanol (63)	Methylbromide (600)	Phosphine (83)
Bis-Chloroethyl Ether (20)	Ethyl Acetate (8)	Methyl Methacrylate (11)	Tetrachloroethylene (100)
Boron Tribromide (2)	Ethyl Formate (10)	MTEB (30)	1,1,1-Trichloroethane (19)
Boron Trifluoride (56)	Ethylene (50)	Naphthalene (38)	Trichloroethylene (27)
1,3-Butadiene (50)	Formic Acid (50)	n-Butyl Acetate (38)	Trichloromethane (7)
1-Butene (120)	Freon 134a (8)	n-Butyl Alcohol (79)	Triethylamine (62)
2-Butene (190)	GA (Tabun) (7)	Nitric Acid (50)	Triethylphosphate (3)
Carbon Tetrachloride (2)	GB (Sarin) (5)	Nitrogen Trifluoride (7)	Trimethylamine (93)
Carbonyl Fluoride (8)	Germane (15)	Phosphorus Oxychloride (20)	Trimethyl Phosphite (4)
Carbon Tetrafluoride (1)	Hexafluoroacetone (4)	Propyl Acetate (7)	Vinyl Acetate (6)
Chlorodifluoromethane (6)	Isobutylene (150)	Propylene (37)	

ASPECT

Detection Limits



- Detection limits are referenced to methanol
 - **Methanol** DL based on both laboratory and field observations
 - **DL is defined as a signal to noise ratio of 3**
 - Passive laboratory measurements are referenced to an active bench top FTIR
 - All data is collected at **16 cm-1 resolution**
 - **A 5° C temperature difference is used**
- Spectra from published libraries are used to develop detection limits for other compounds
- Library spectra is either decimated or smoothed to 16 cm-1 resolution and the appropriate absorbance is obtained.
- A ratio is used between the absorbance and detection limit of methanol to the other compound:

$$\text{Chemical X DL} = (\text{Methanol DL})(\text{Chemical X Absorbance})/(\text{Methanol Absorbance})$$

ASPECT

Rapid Assessment of Field Data using an Empirical Sensor Model Verified Against Lab and Field Data

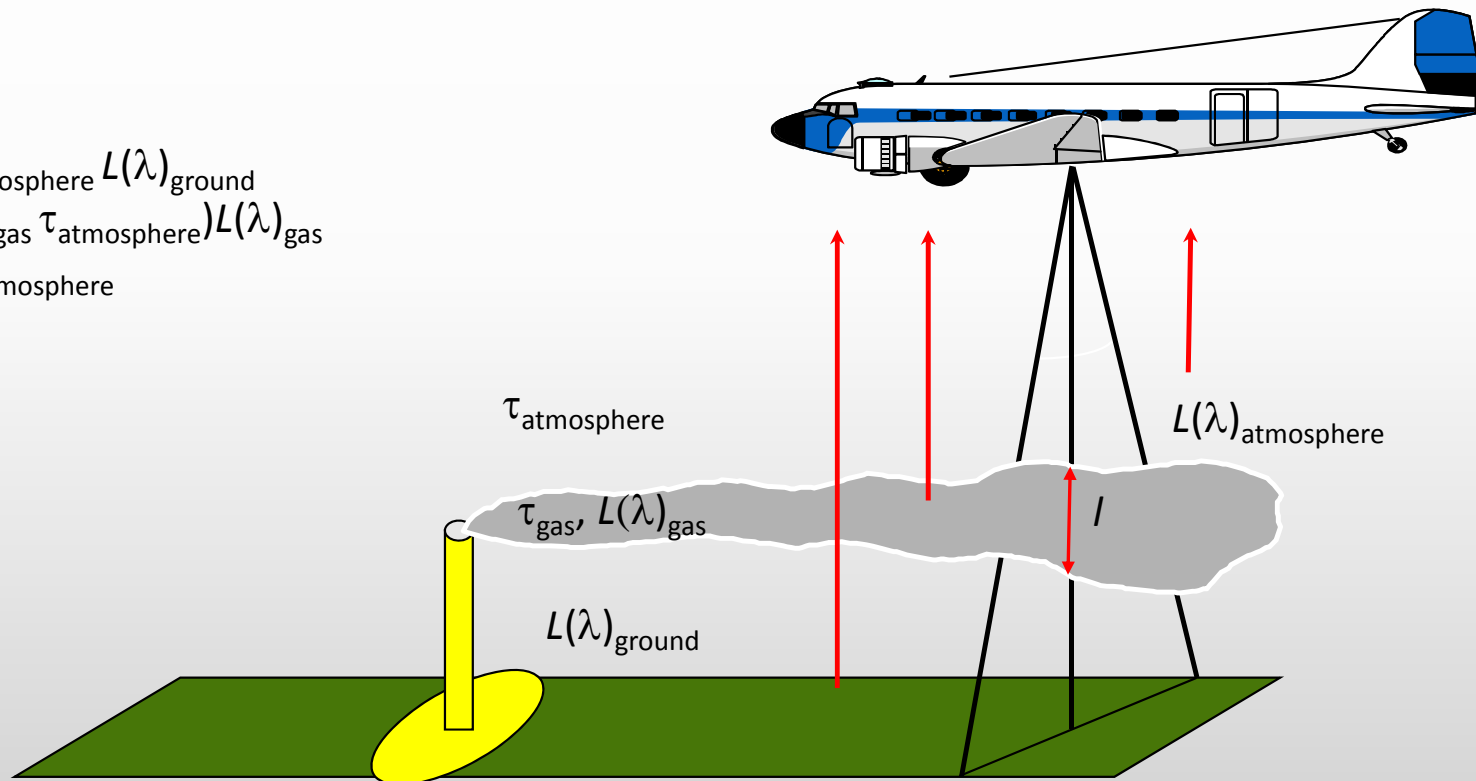


- Typical Laboratory Spectroscopy: where: A = Absorbance
 $A = \log_{10}(P/P_o)$ P/P_o = Ratio of Signal to Background
- Beer's Law: where A = Absorbance
 $A = E \cdot b \cdot C$ where: E = Emissivity
 b = Path length
- With Substitution:
 $E \cdot b \cdot C = \log_{10}(P/P_o) \rightarrow C = (\log_{10}(P/P_o)) / (E \cdot b)$
- Assumptions:
 - The Kalman score output from the pattern recognition provides a rough first order estimator of the signal intensity in a spectrum for a gaseous species detected against the background effects
 - A score = 0 defines the system detection limit
 - A score = 1.0×10^{-13} defines the background score
 - For a large release a path of 50 meters is used, for a small release a path of 10 meters is used.
 - The absorbance, A , is a scaling factor and is adjusted to fit the data
 - A constant instrument and vapor/background temperature is assumed
 - Errors tend to be large (100%) so the method provides a screening result of low, medium, and high
- With Substitution of the Kalman Score:
 $C = (1/E \cdot b)(\log_{10}(\text{Kalman Score}) / (\text{Kalman Background}))$
- Referenced to the Detection Limit, DL:
 $C = DL/b + (1/E \cdot b)(\log_{10}(\text{Kalman Score}) / (\text{Kalman Background}))$

ASPECT Radiometric Model

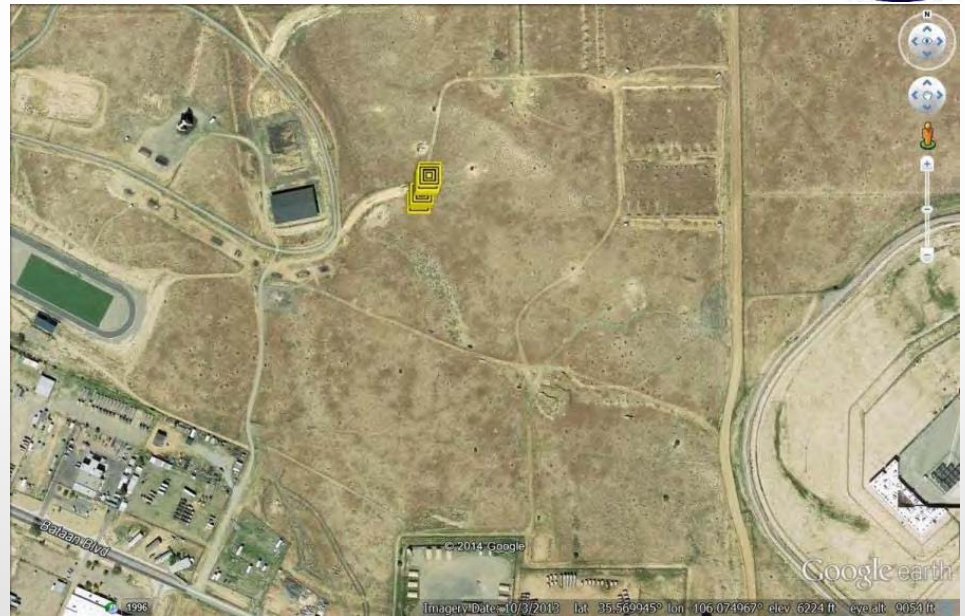


$$L(\lambda)_s = \tau_{\text{gas}} \tau_{\text{atmosphere}} L(\lambda)_{\text{ground}} + (1 - \tau_{\text{gas}} \tau_{\text{atmosphere}}) L(\lambda)_{\text{gas}} + L(\lambda)_{\text{atmosphere}}$$



US EPA ASPECT

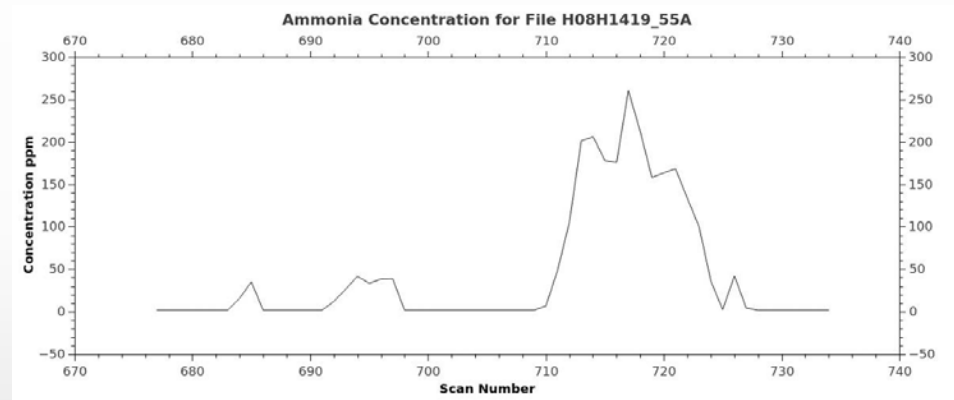
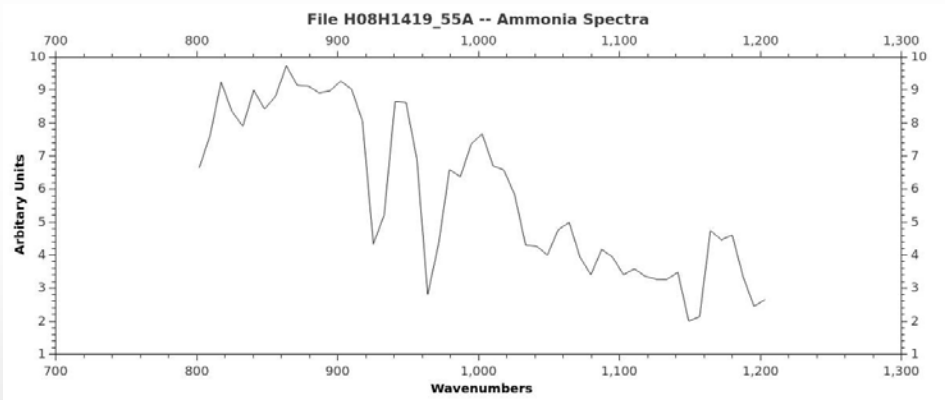
Rapid Assessment of Field Data using an Empirical Sensor Model Verified Against Lab and Field Data



Ammonia Detection for File H08H14190_55A and Close-up
2014 New Mexico 64th CST Exercise – one FTIR sample path by the aircraft over the target

US EPA ASPECT

Rapid Assessment of Field Data using an Empirical Sensor Model Verified Against Lab and Field Data

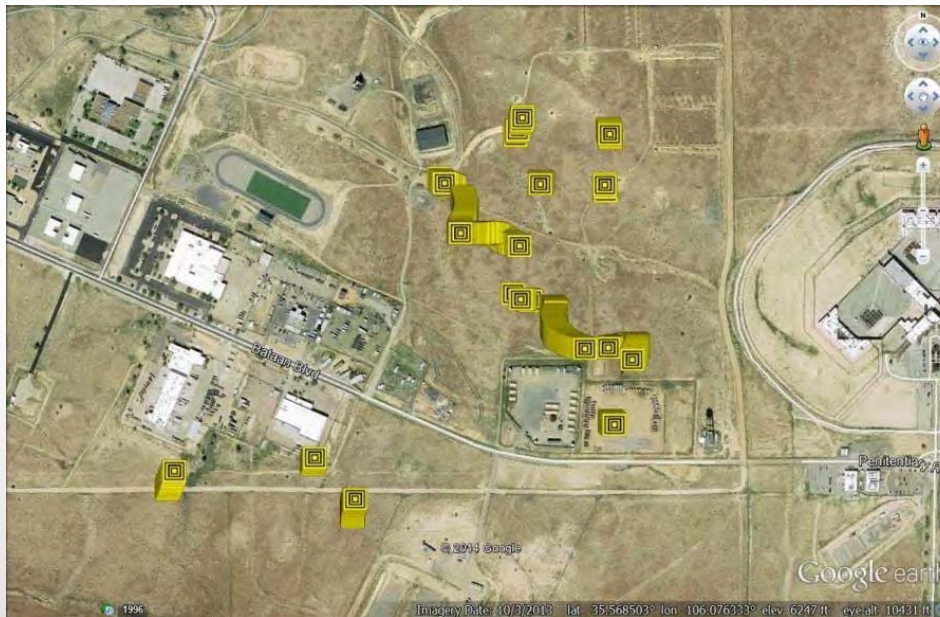


Confirmation Ammonia Spectra and Rapid Assessment Data for an Estimated Plume (11.5 meter Plume Thickness)

2014 New Mexico 64th CST Exercise

US EPA ASPECT

Rapid Assessment of Field Data using an Empirical Sensor Model Verified Against Lab and Field Data



Locations of All Ammonia Detections
2014 New Mexico 64th CST Exercise

ASPECT Optical/IR Sensor Layout

Bottom View

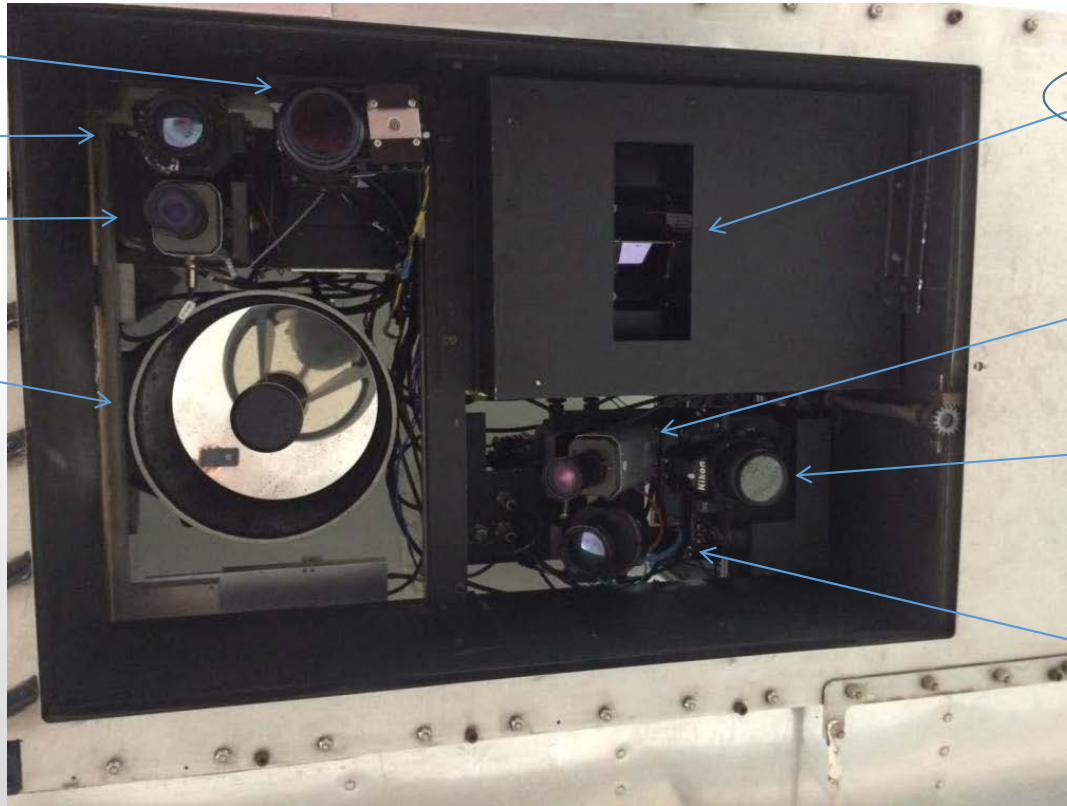


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Visible Targeting Camera

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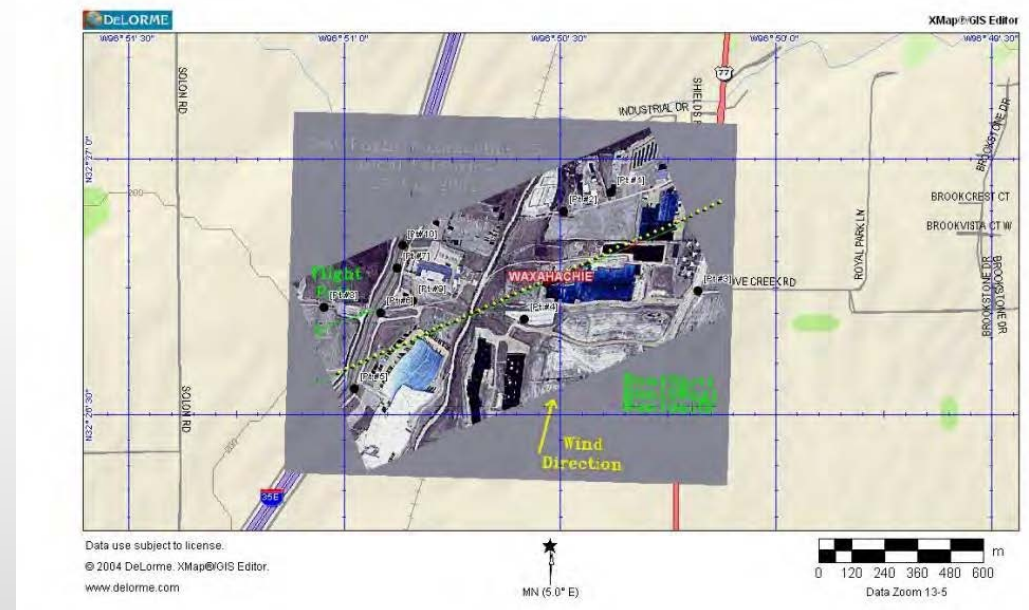
← Front

ASPECT

Line Scanner RS-800MSIRLS

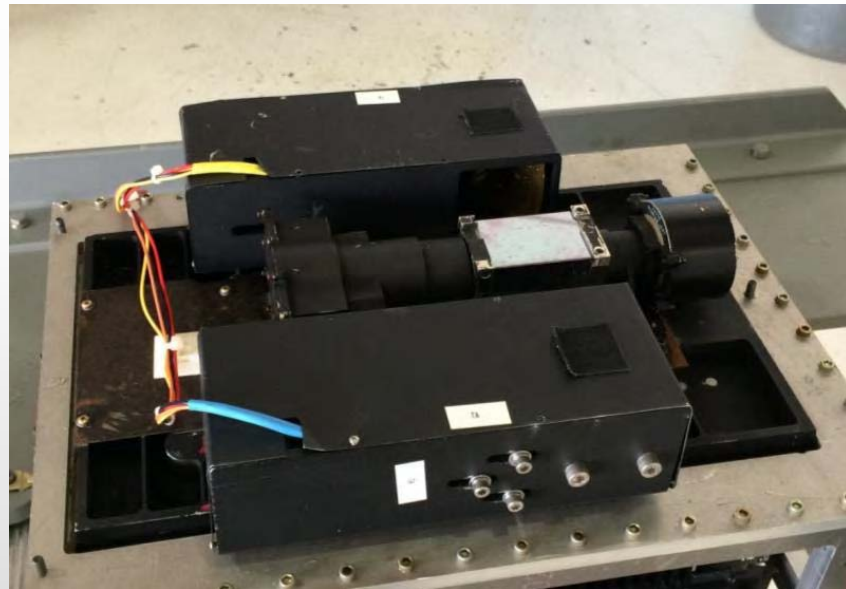


- Using a scanner speed of about 60 Hz and a field of view of 60° results in a linear infrared image approx ½ mile wide.
- Approx 2.0 square miles can be imaged per minute.
- Chemical Discrimination is accomplished using a matrix of 16 cold optical filters having a bandwidth of approx 5 – 10 wavenumbers
- Data Collection Status in approximately 12 minutes from Start-up

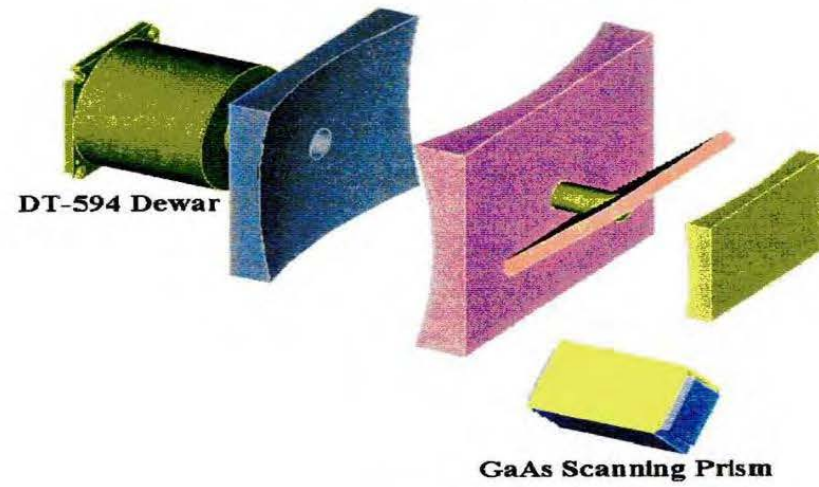
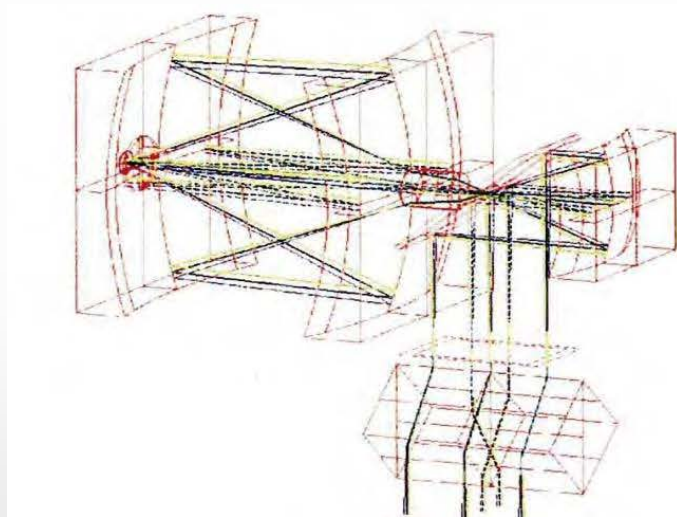


ASPECT

RS-800MSIRLS Line Scanner Detail



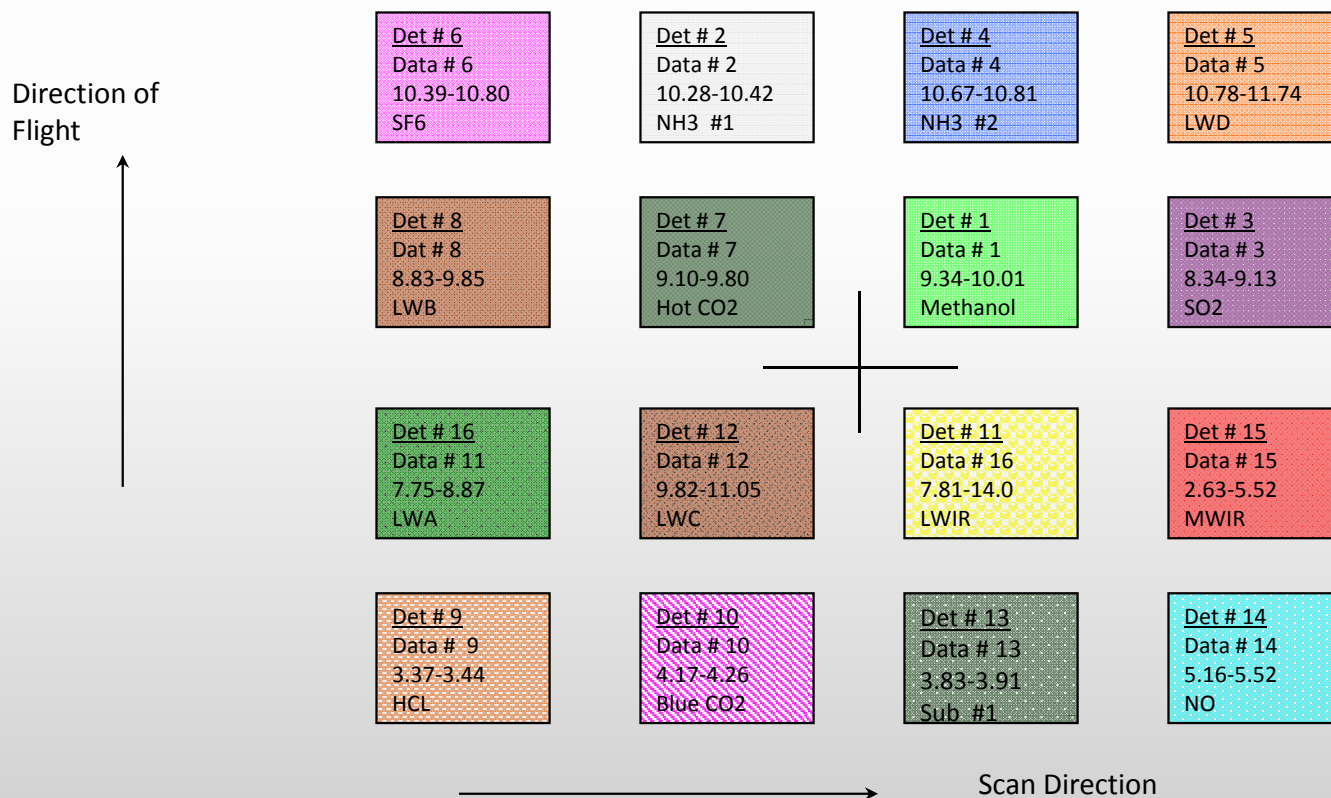
RS-800MSIRLS Line Scanner Design



The RS800 consist of a rotating scanning prism with focusing reflective optics. The RS800 is very efficient in both optical throughput and f-number.

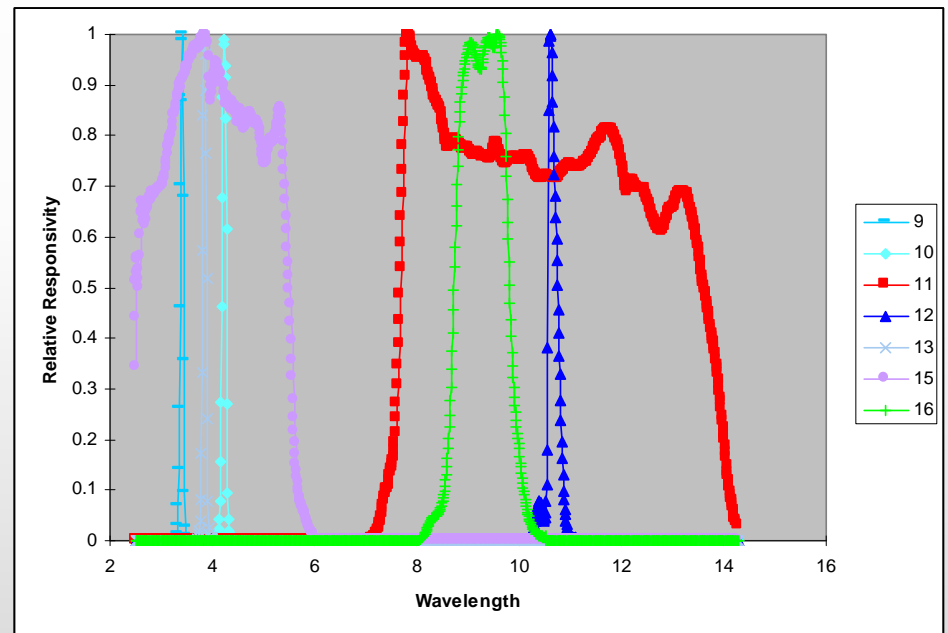
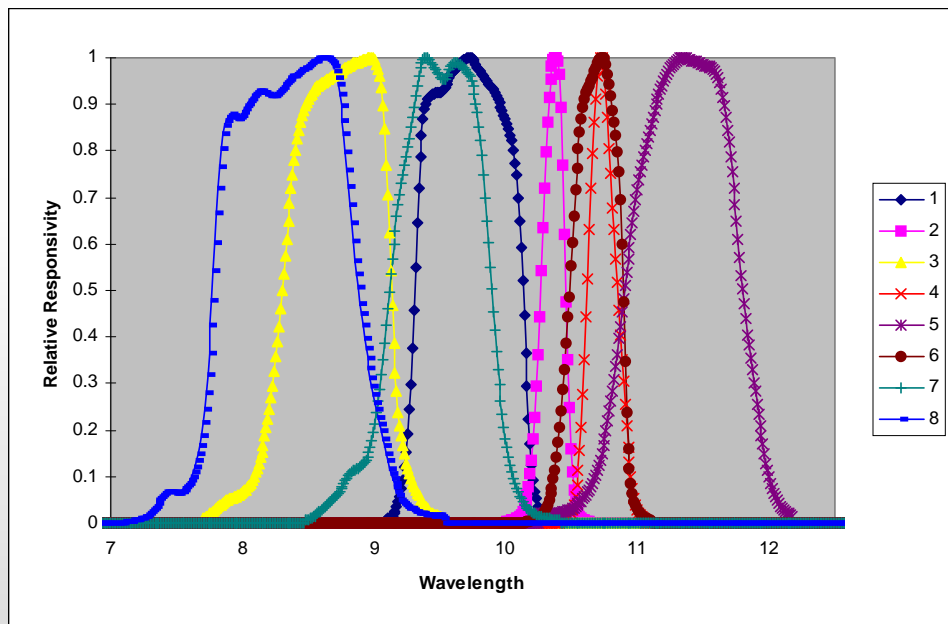
ASPECT

RS-800 Detector Layout



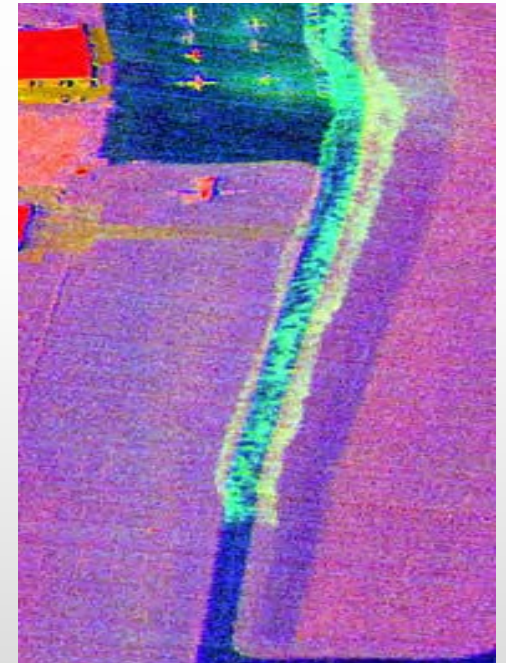
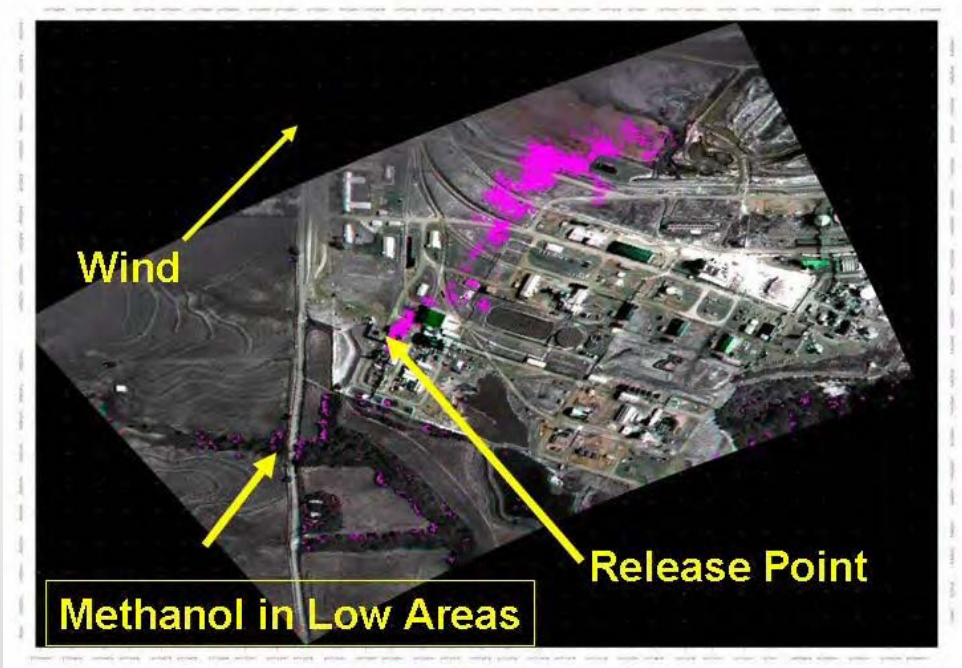
ASPECT

RS800 Bandpass Filter Response



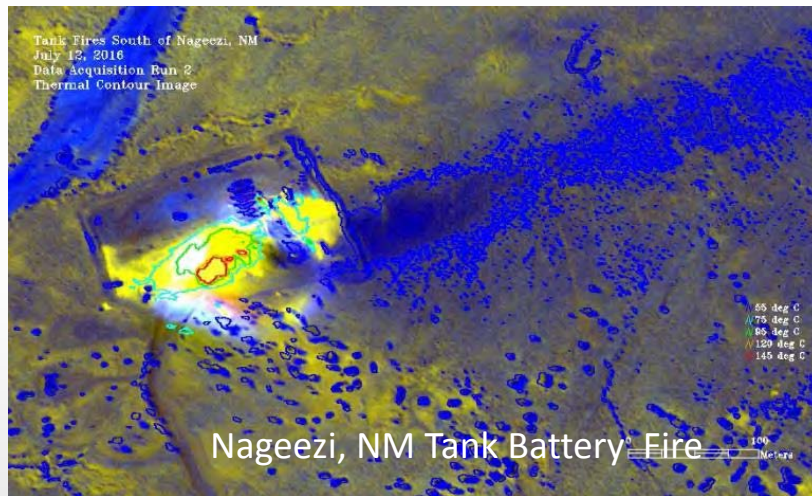
ASPECT

Methanol and Ethanol Imagery



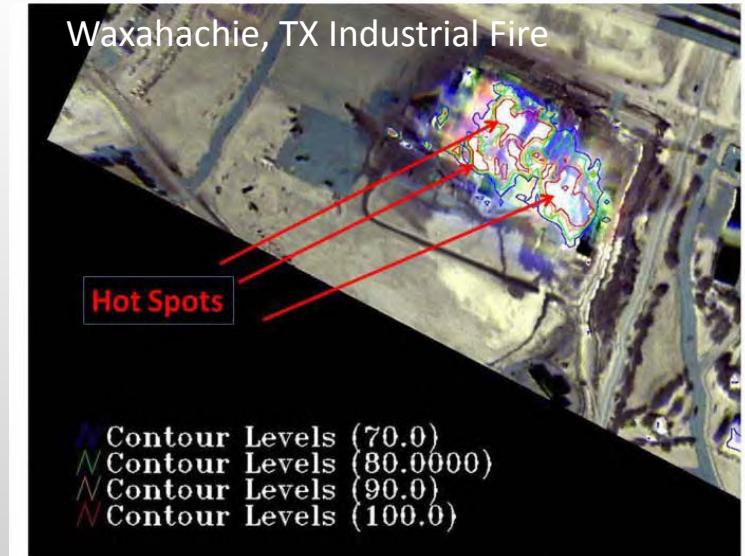
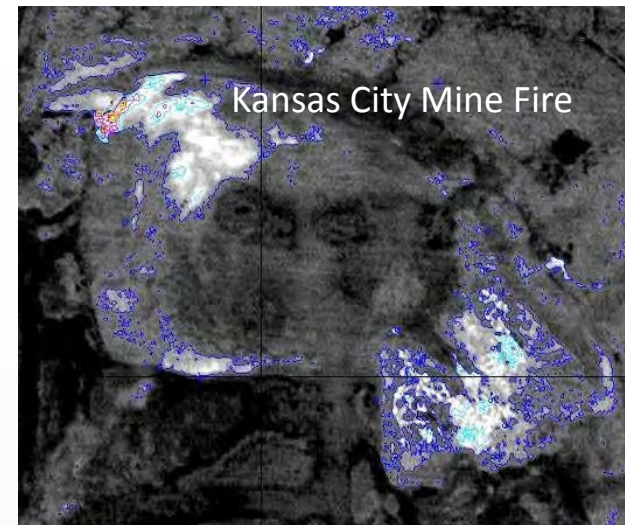
ASPECT

Thermal Products



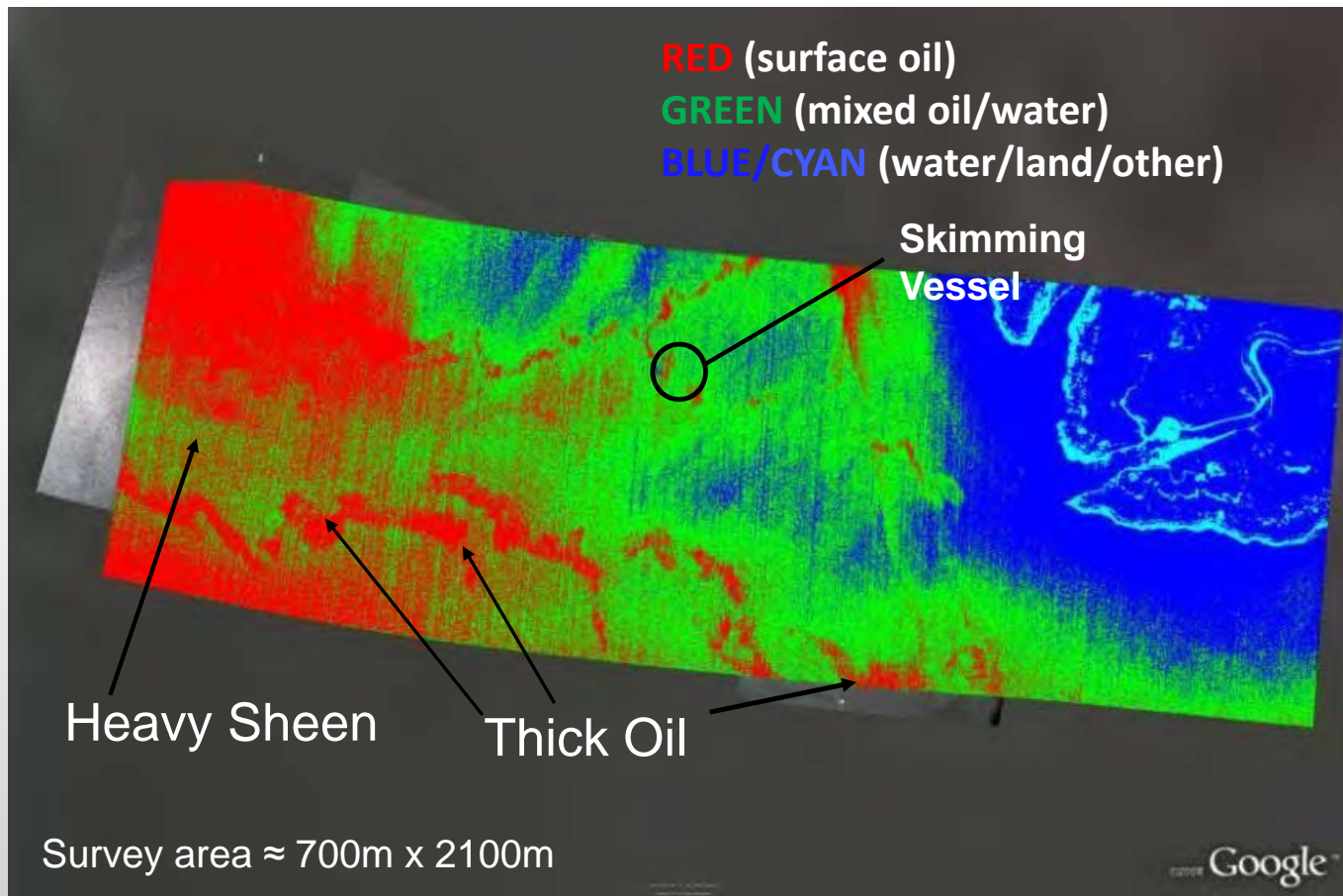
Long wave Thermal Specifications:

- Pixel Size = 0.5 M
- Linear Range = Up to 200 C
- Resolution = 0.05 C



ASPECT

Supervised Classification Of Oil on Water



ASPECT Optical/IR Sensor Layout

Bottom View

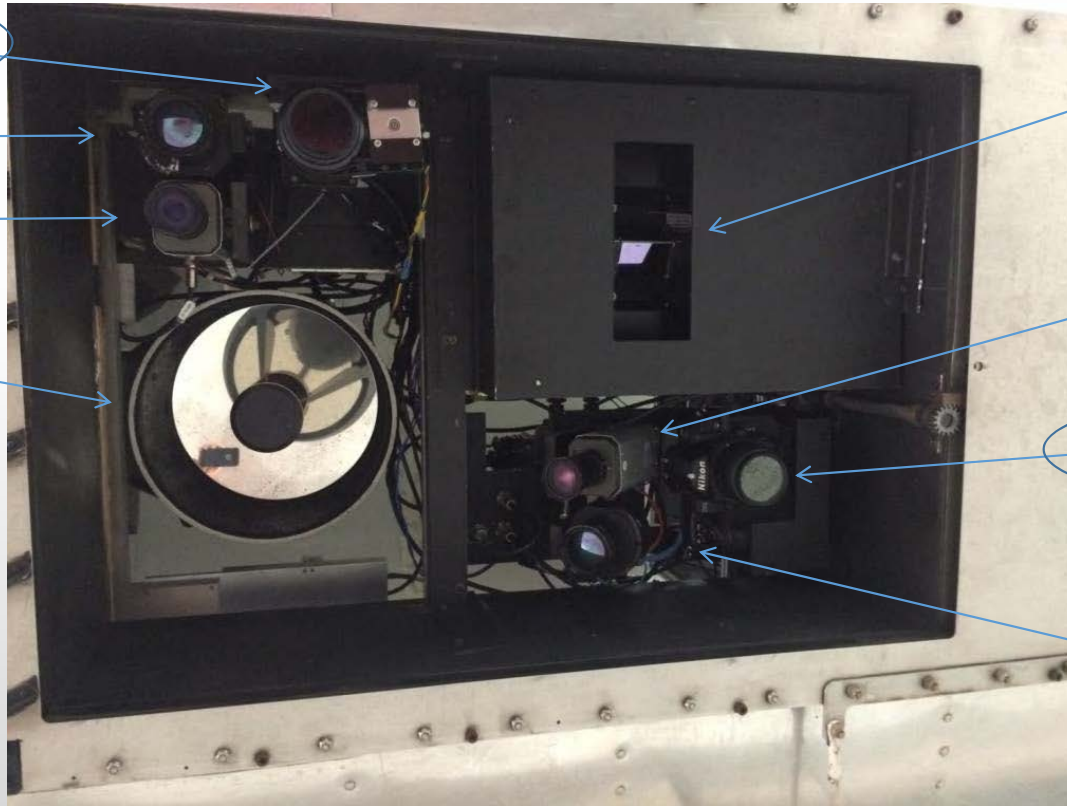


MSIC Mapping Camera

IR Targeting Camera

Visible Targeting Camera

Spectrometer Telescope



RS80/LS1600 IR Scanner

Visible Forward Targeting Camera

Nikon D2X Camera Reserve

IR Forward Targeting Camera

← Front

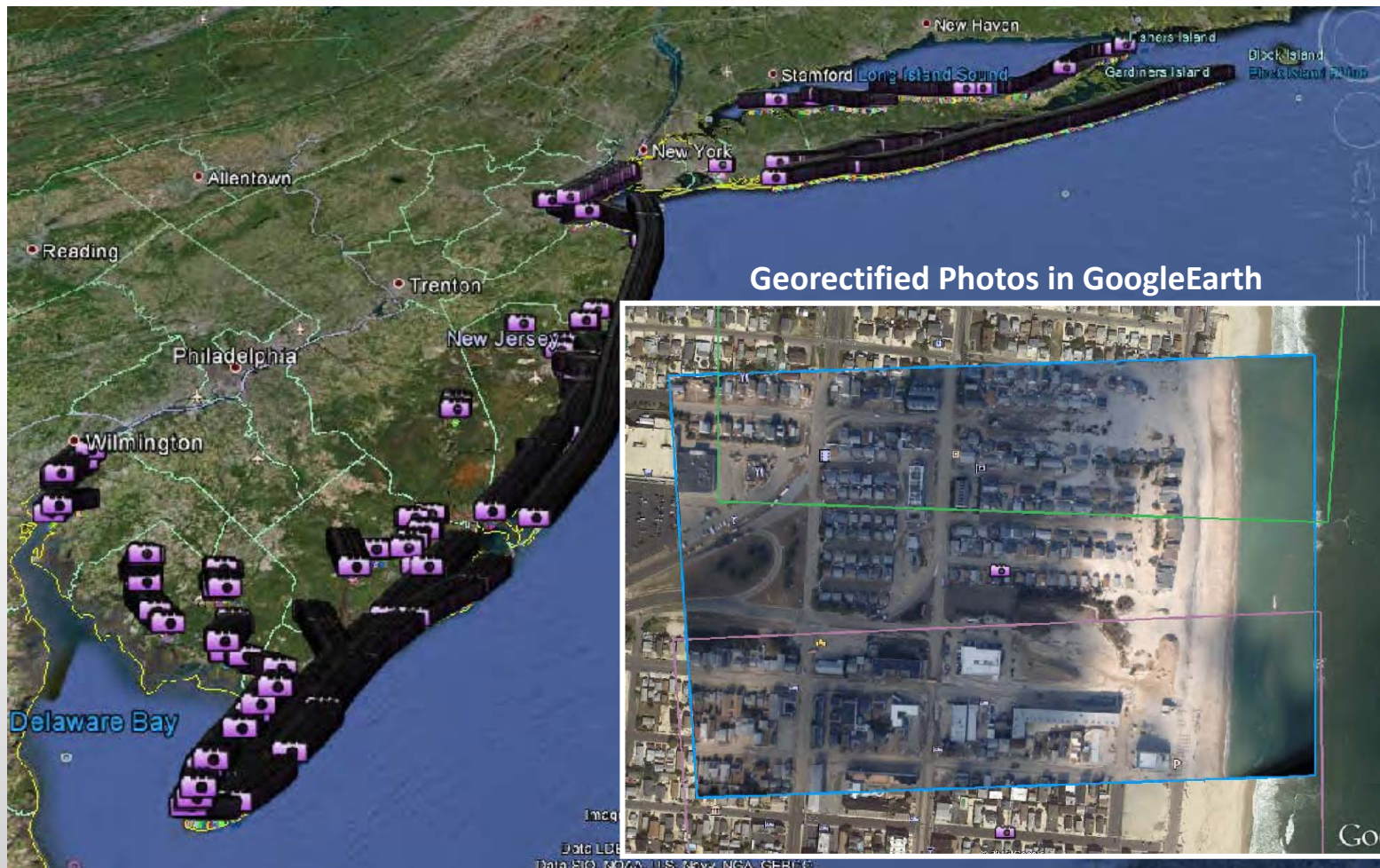
ASPECT

Aerial Photography

- 29 MP High Resolution Mapping Camera and a secondary 12.5 MP DSLR Camera.
- Automatically slaved to the IR sensors
- Automated Geo-Rectification/GIS Coded Images
- Full Ortho-Rectification (Terrain and Camera Model) Correction
- Ability to Process in the Air-Approx. 3 Minute Turn-Around
- Compressed Transmission of Data Via SatCom
- Fast Turn Around on Images – Approx. 1000 processed images per Mission
- All Products can be imported into:
 - ✓ Google Earth,
 - ✓ ESRI
 - ✓ Generic Geospatial software packages
 - ✓ *Respective Packages Easily Selectable*



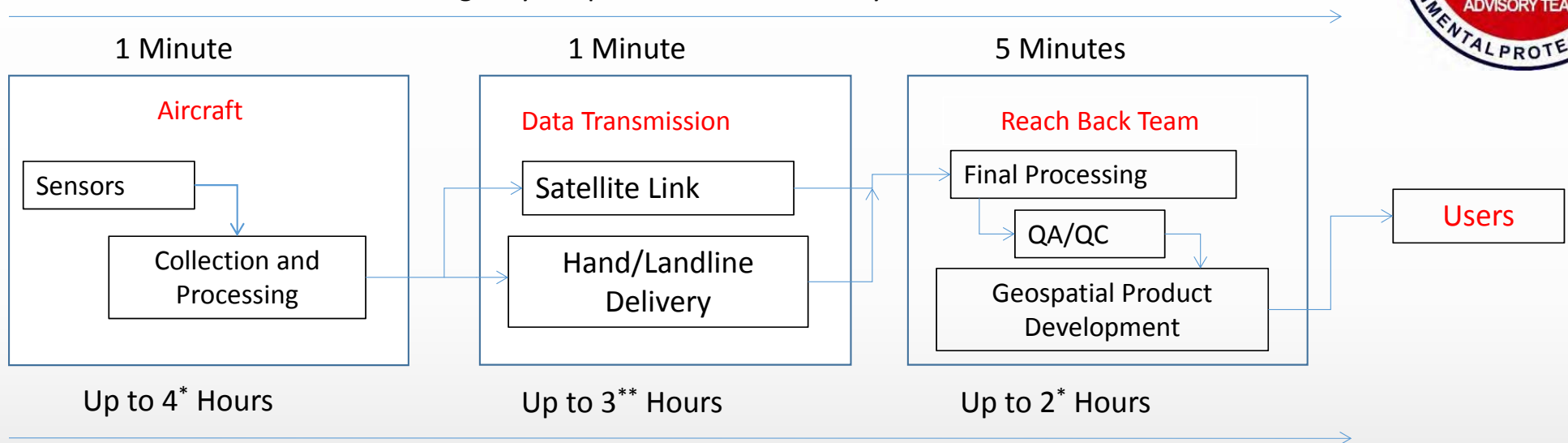
Hurricane Sandy Response



DATA PROCESSING AND DELIVERY TIME



Emergency Response --- Data Delivery \approx 5 Minutes



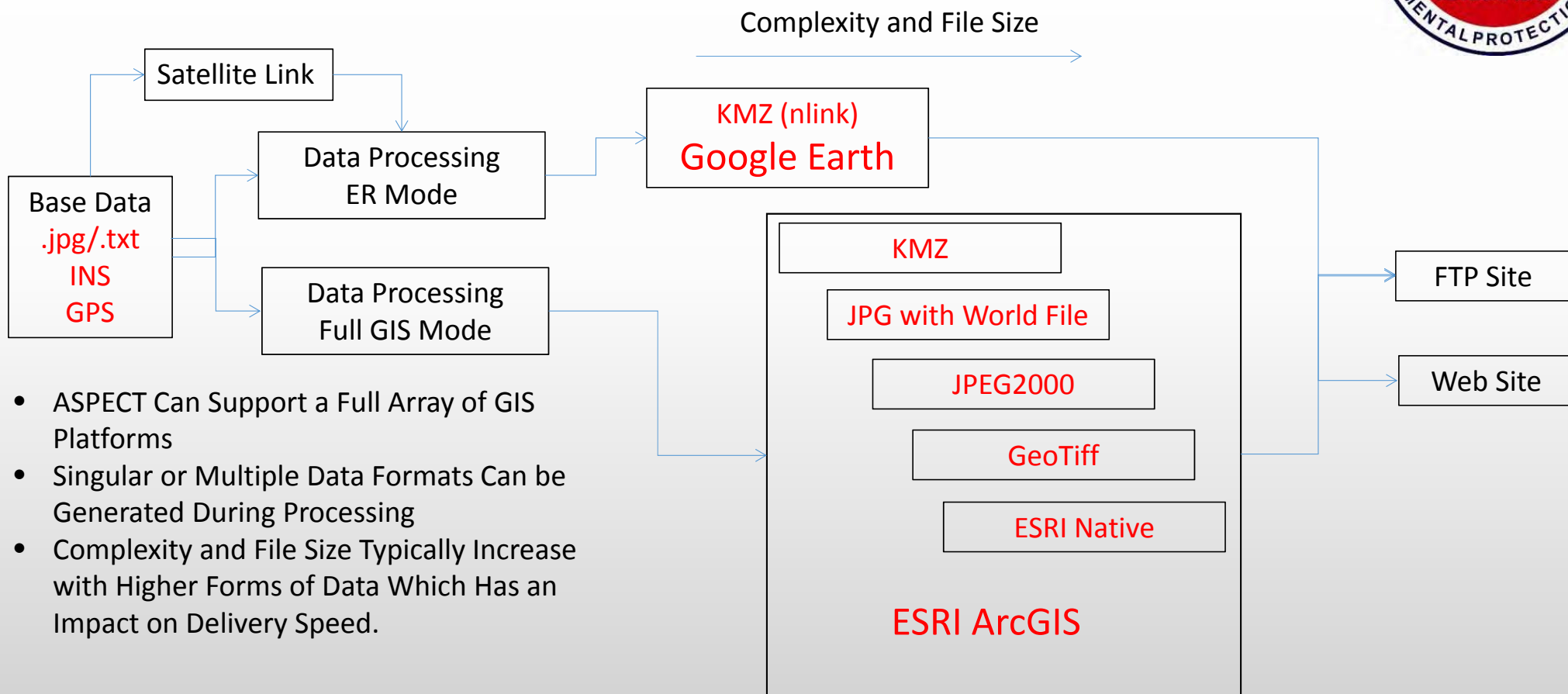
Non Emergency Response/Survey --- Data Delivery \approx Up to 9 Hours

* Dependent on the size and complexity of the survey area. 5 hours represents the maximum on-station capability of the aircraft.

** Dependent on the available bandwidth for data transmission. A high speed connection will minimize this time estimate.

ASPECT

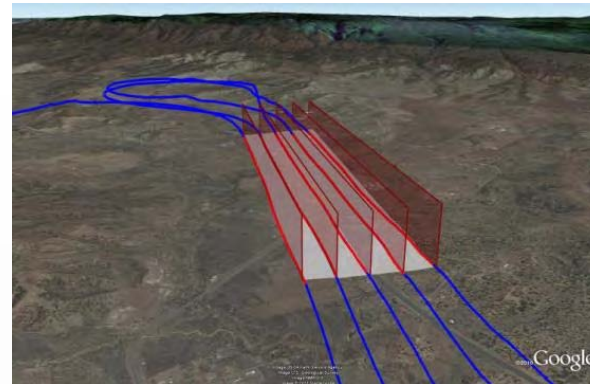
GEOSPACIAL PRODUCT DEVELOPMENT



ASPECT

Mission Design

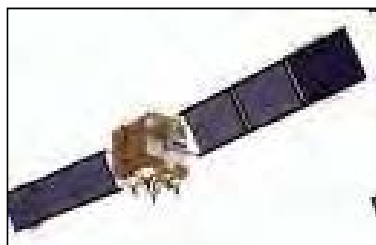
- Initial Flight Design using Flight Profiles and/or Flight Lines
- Generation of a Mission Order
- Analysis of Flight Hazards
- Constant Review of Weather
- ASPECT real-time quality checks on flight paths and altitudes
- For Emergency Response Actions, Sections of Mission Planning are Conducted in the Air.
- Nav/Flight Line Data is Generated Using Custom Software and Can be Uploaded While the Aircraft is in Flight.



ASPECT – Data QA/QC & Dissemination



****Performed in about 5 minutes****



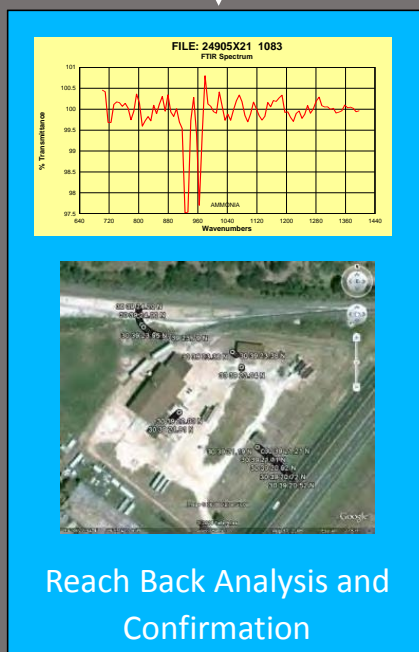
Compressed data package
sent via satellite

Automated airborne
processing and packaging

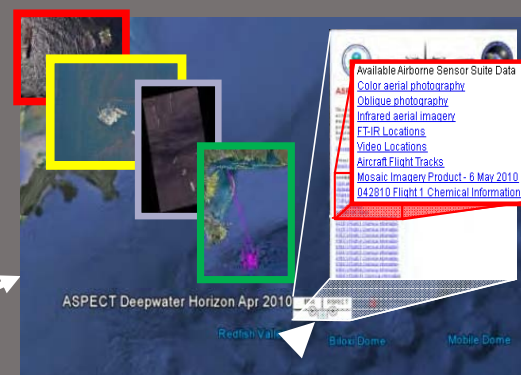
Chem/Rad/Situational
data collected



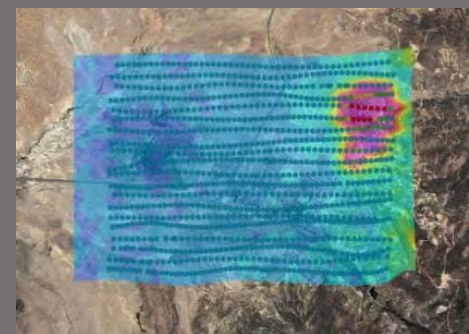
Data package unzipped by
scientific reach back team



Reach Back Analysis and
Confirmation

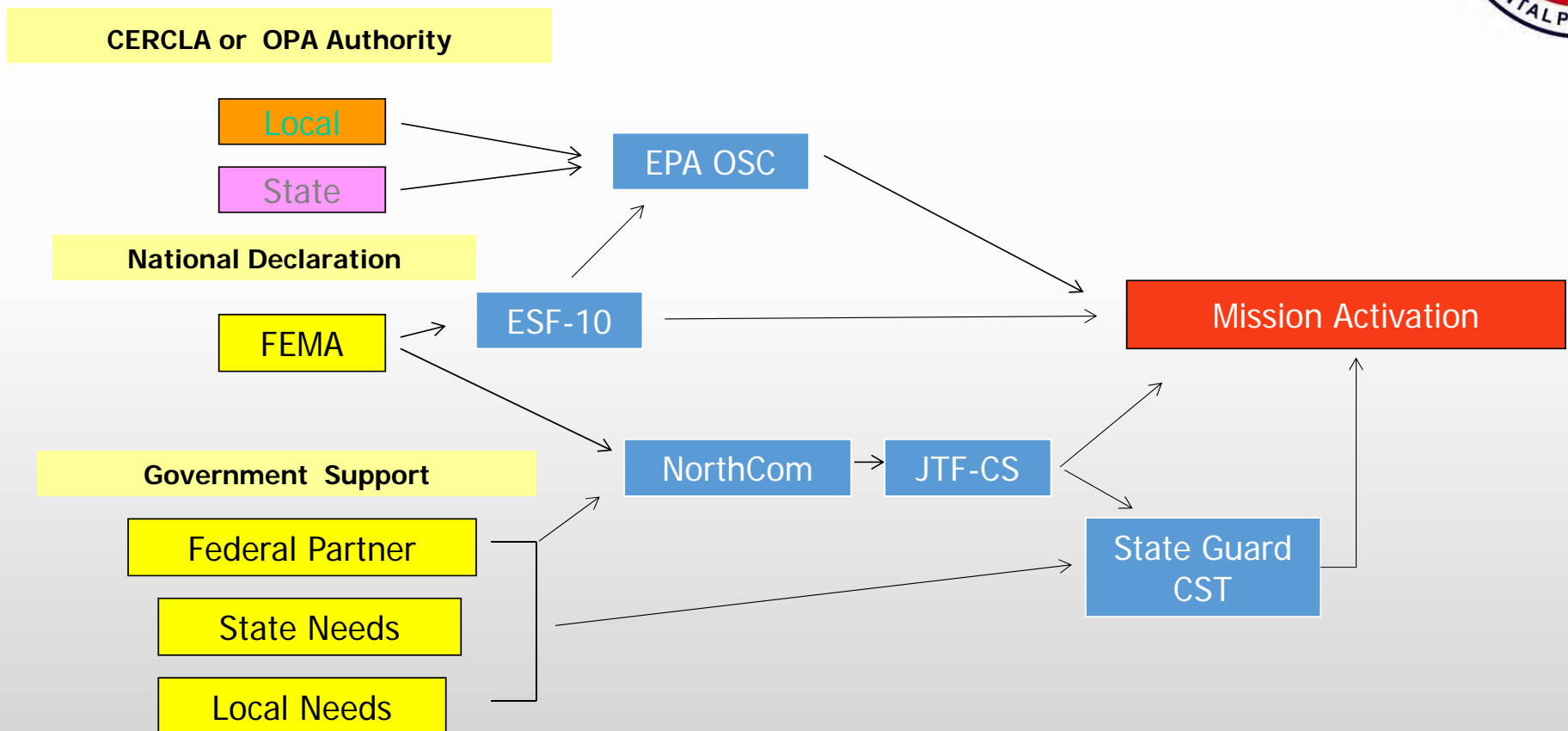


Data dissemination using
Google Earth/ESRI

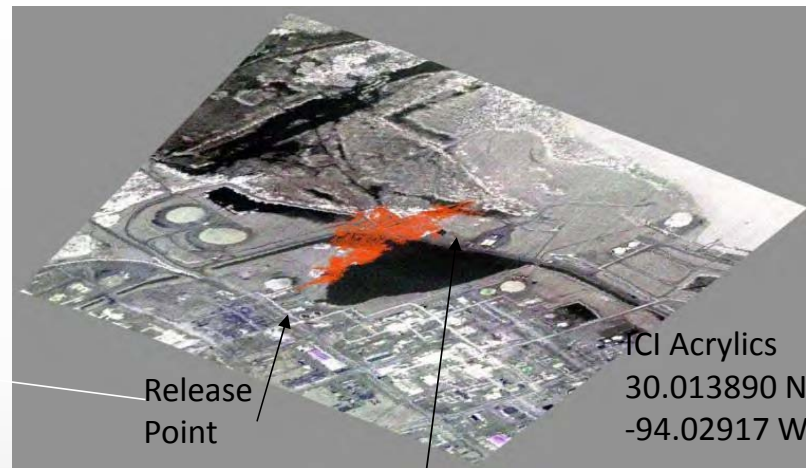
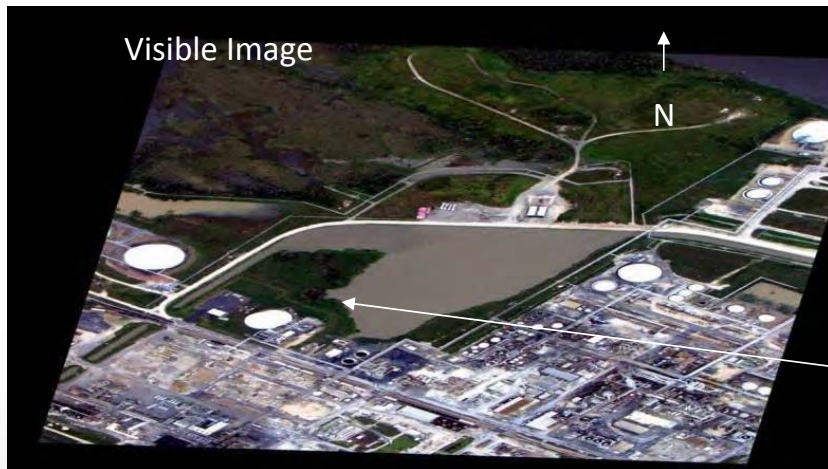


ASPECT

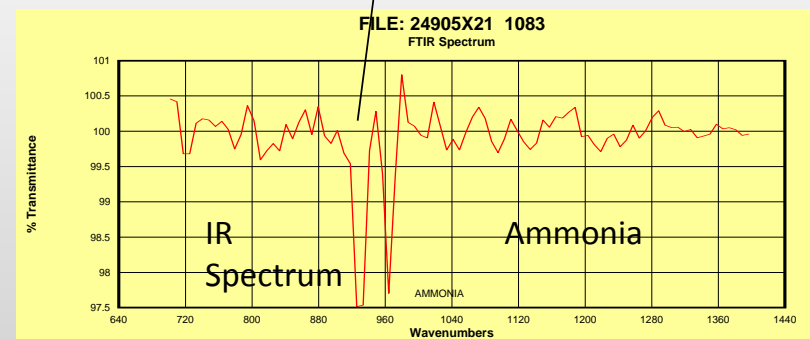
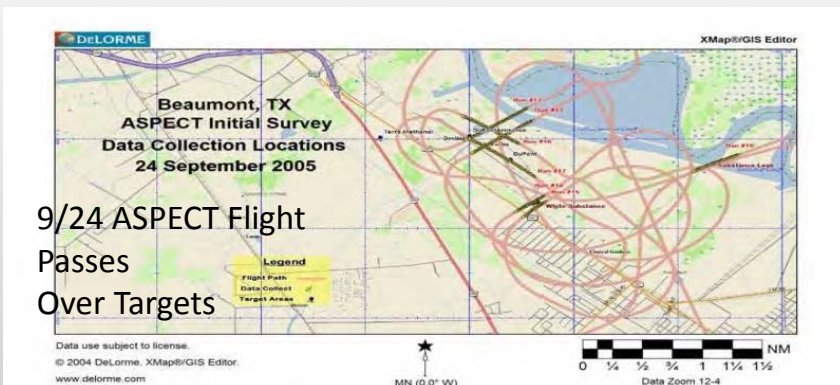
Methods of Activation



ASPECT – Hurricane RITA Response 9/24/2005



Plume Identification and Classification



ASPECT – Hurricane RITA Response 9/25/2005

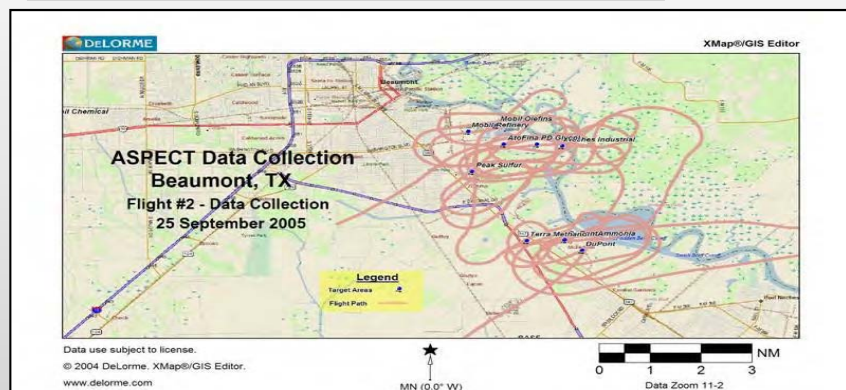
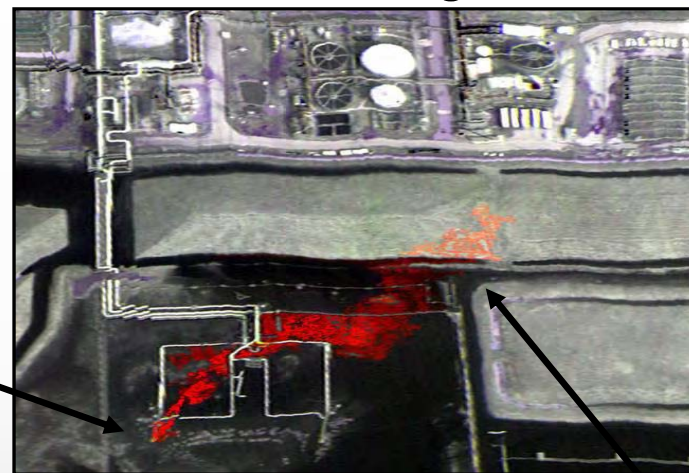


Beaumont,
Texas

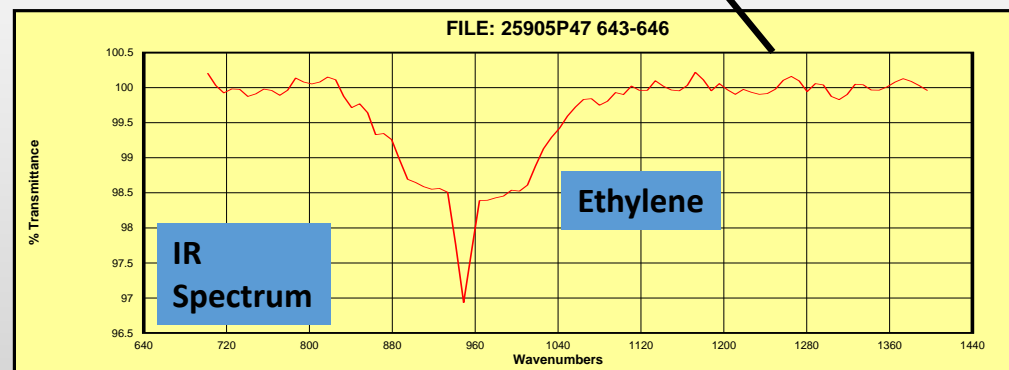
30.06537 N
-94.0633 W

Release
Point

IR Image



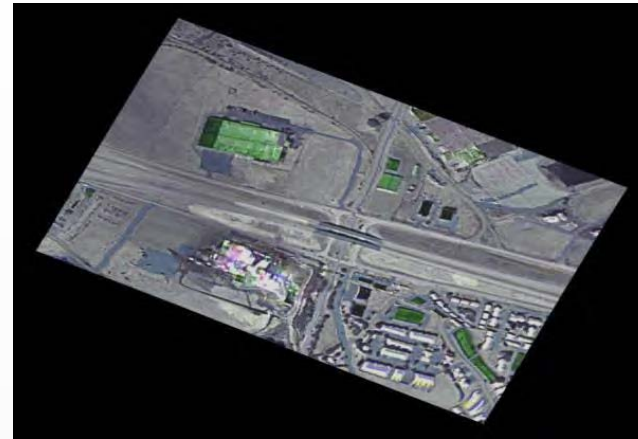
9/25 ASPECT Flight Passes Over Targets



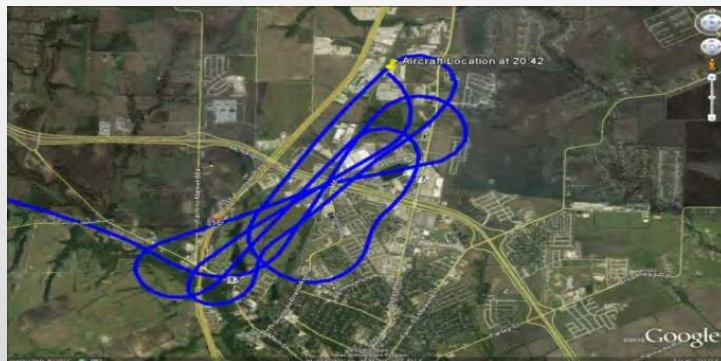
ASPECT – Magnablend Fire – 3 Oct 2011



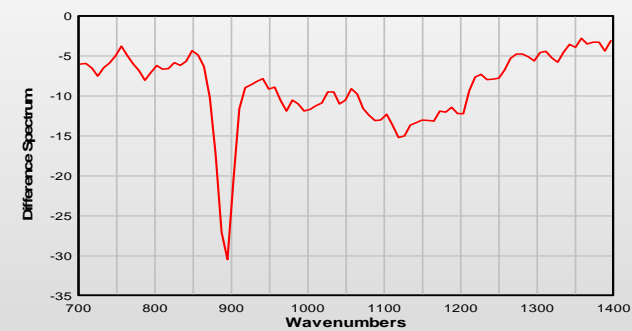
Visible Image



IR Image



Flight Path

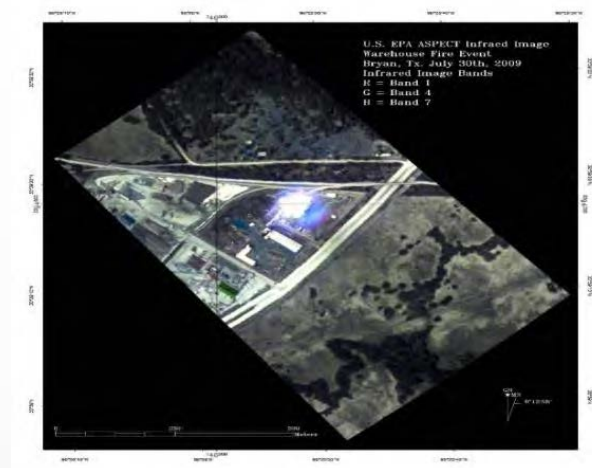


Isopropylene Spectrum

ASPECT – El Dorado Chemical Fire – 30 July 2009



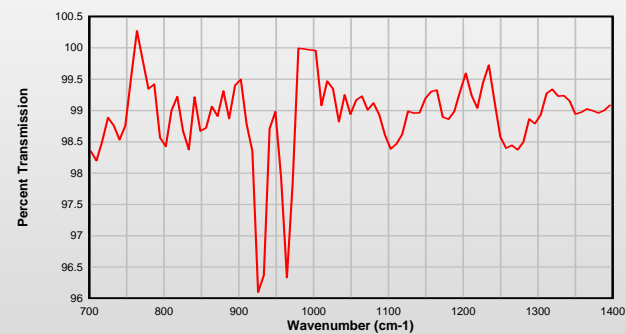
Visible Image



IR Image

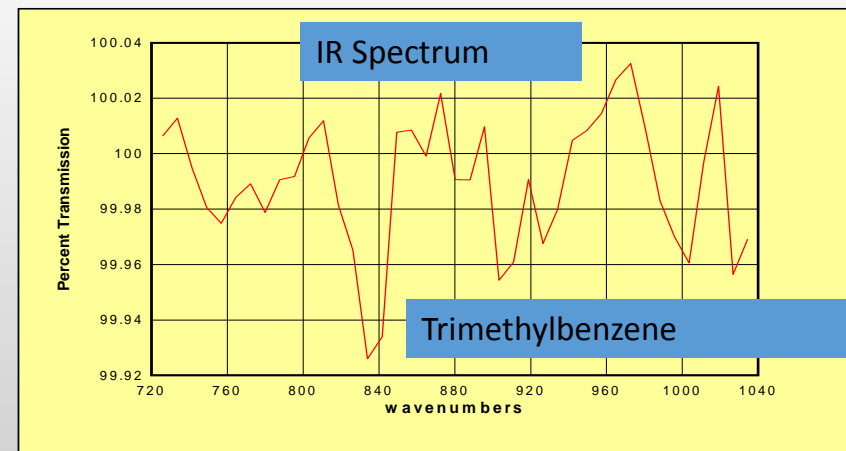
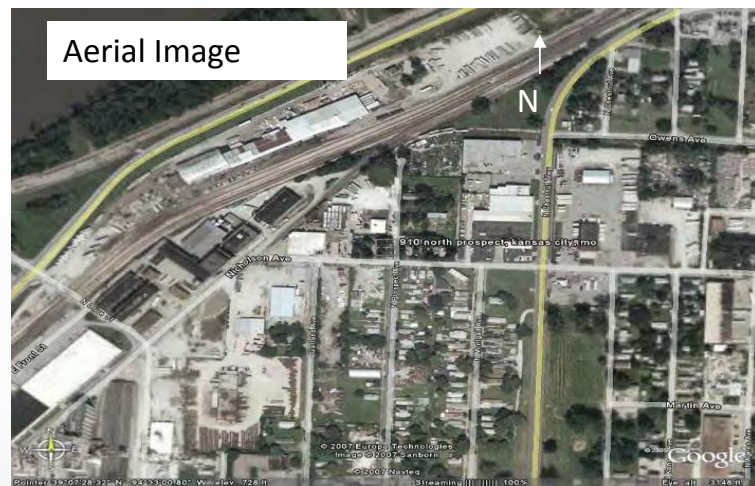


Flight Path

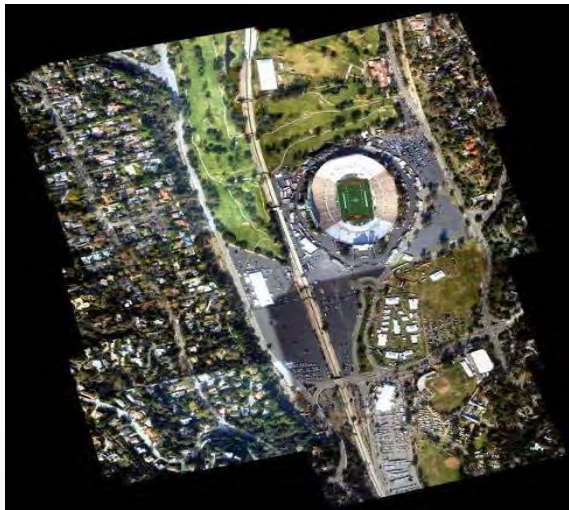


IR Spectrum

ASPECT – Chem Central, Kansas City, MO--7 February 2007

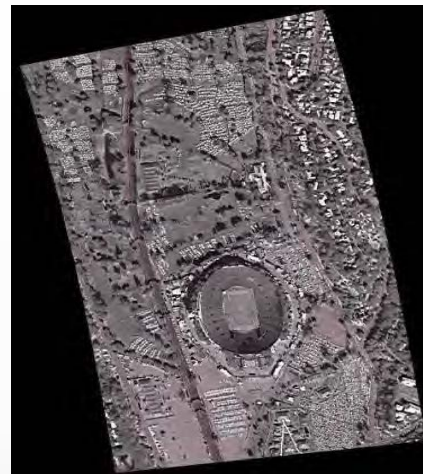


ASPECT – Rose Bowl Pasadena CA –1 January 2008

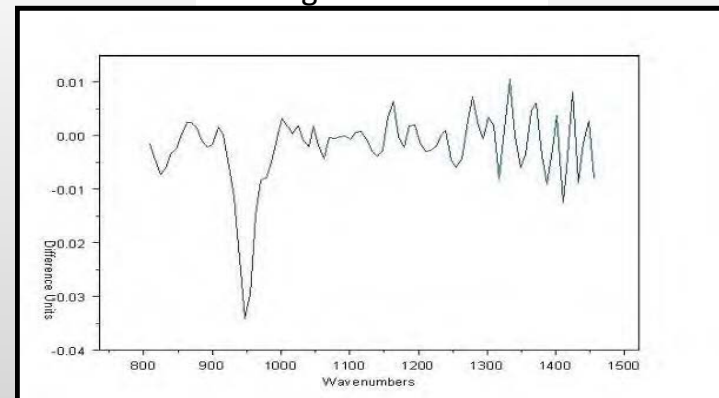


Aerial Image

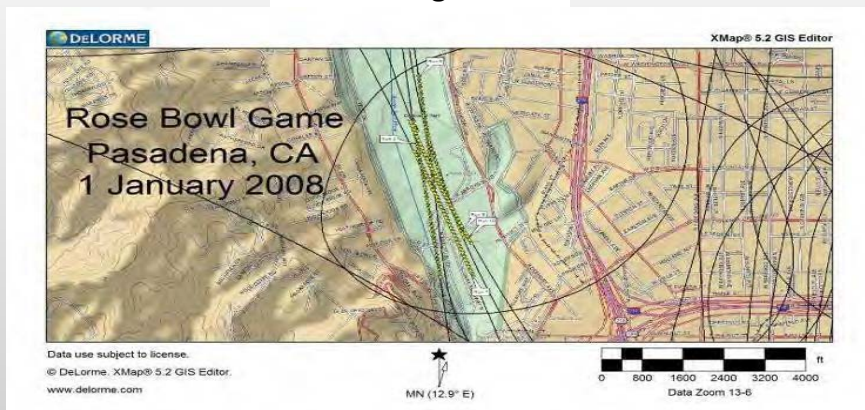
↑
N



IR Image



Ethylene Spectrum

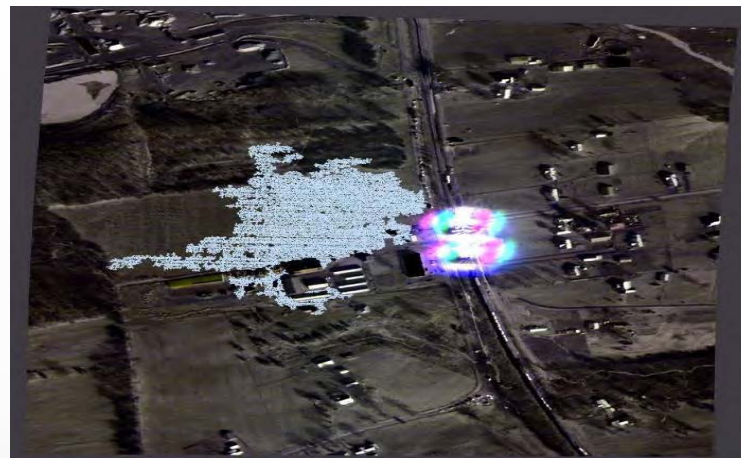


ASPECT – Shepherdsville Train Derailment -- 17 January 2008

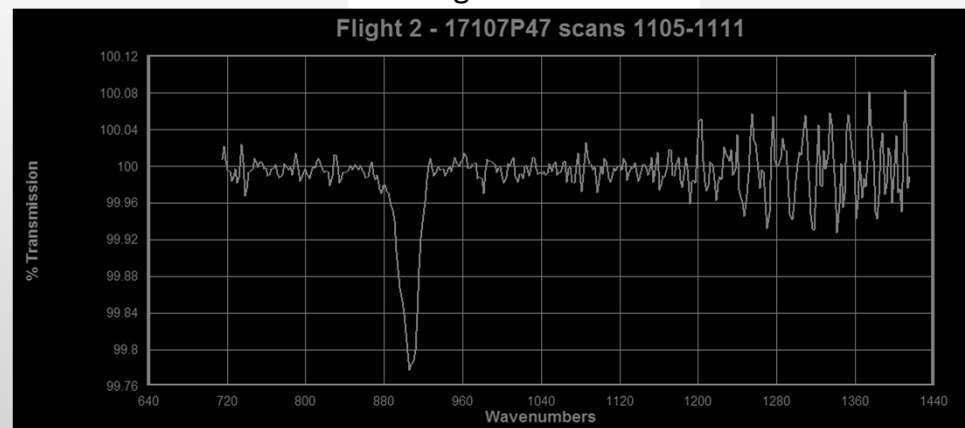
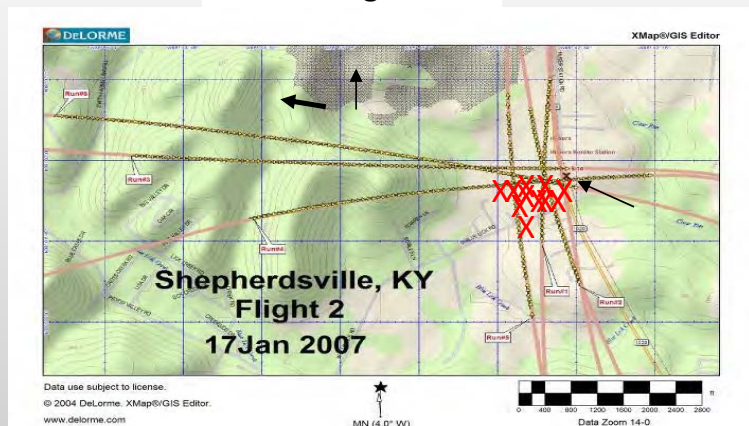


Aerial Image

↑
N



IR Image

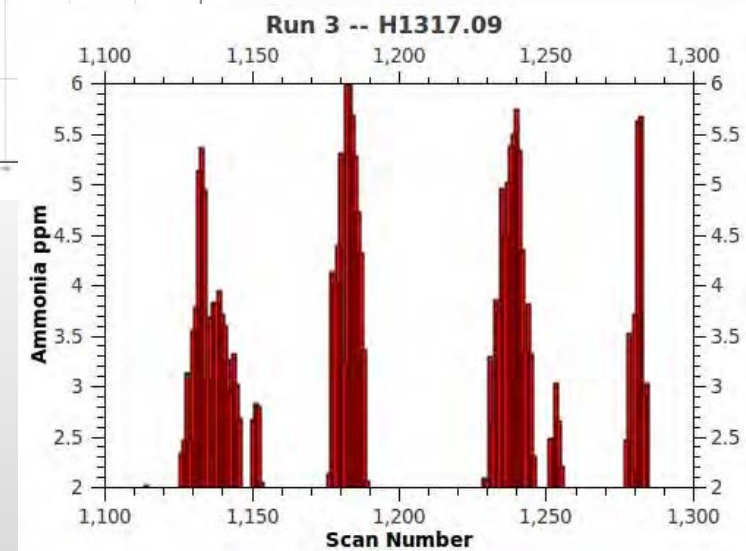
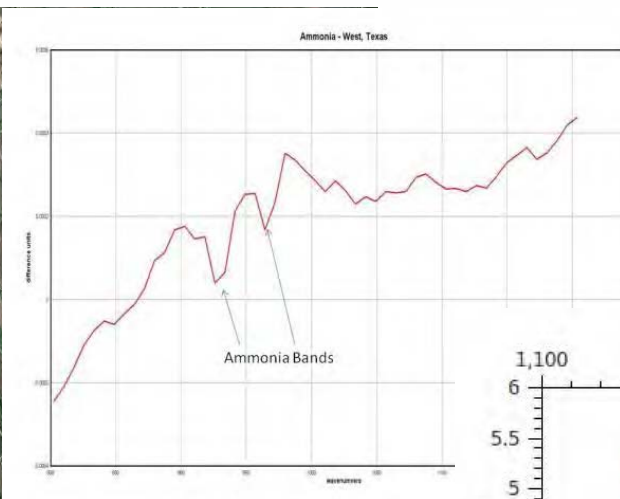
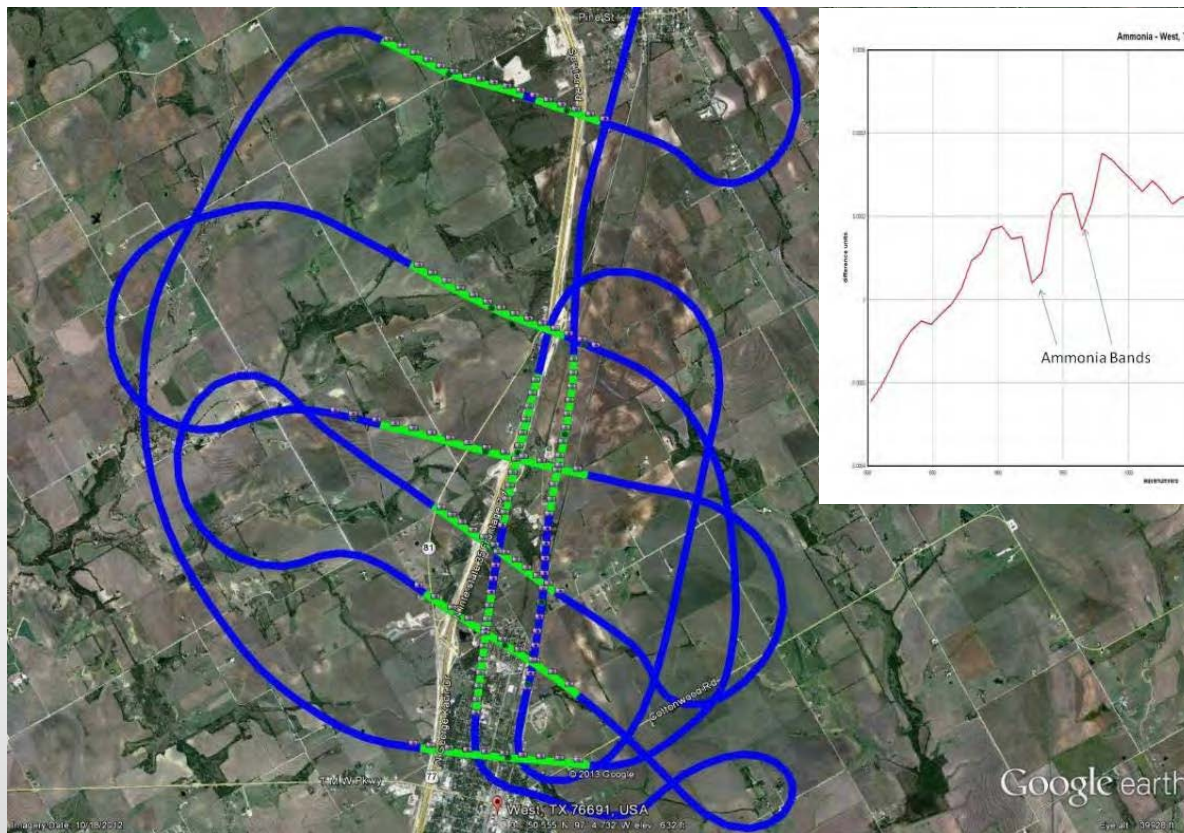


1,3-Butadiene Spectrum

ASPECT -- West, TX Explosion Response – 18 April 2013



ASPECT -- West, TX Explosion Response – 18 April 2013



18 April 2013 – 0000 Local

Contact and Readiness



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Readiness - 24/7/365 On-Call

1 Hour Wheels-up!